595

AMERICAN JOURNAL OF PHYSICAL ANTHROPOLOGY

Founded by Aleš Hrdlička, 1918

MANAGING EDITOR

William S. Laughlin
University of Wisconsin

ASSOCIATE EDITORS

Marshall T. Newman
U. S. National Museum

William C. Boyd
Boston University
School of Medicine

Melvin L. Moss
Columbia University

J. Lawrence Angel
Jefferson Medical College

BOOK REVIEW EDITOR

Frederick S. Hulse
University of Arizona

Official Organ of the American Association of Physical Anthropologists

New Series — Volume 19
MARCH, JUNE, SEPTEMBER
DECEMBER 1961

PUBLISHED BY
THE WISTAR INSTITUTE OF ANATOMY AND BIOLOGY
PHILADELPHIA, PA.

Digitized by the Internet Archive
in 2024

https://archive.org/details/american-journal-of-physical-anthropology_1961_19

Contents

No. 1 MARCH 1961

WILLIAM MONTAGNA, KENJIRO YASUDA AND RICHARD A. ELLIS. The Skin of Primates. III. The Skin of the Slow Loris (*Nycticebus coucang*) 1

KENJIRO YASUDA, TSUYOSHI AOKI AND WILLIAM MONTAGNA. The Skin of Primates. IV. The Skin of the Lesser Bushbaby (*Galago senegalensis*) 23

ALEXANDER S. WIENER AND EVE B. GORDON. The Blood Groups of Chimpanzees: The Rh-Hr (CDE/cde) Blood Types 35

STANLEY M. GARN, CHRISTABEL G. ROHMANN AND MEINHARD ROBINOW. Increments in Hand-Wrist Ossification 45

VIRGINIA AVIS. The Significance of the Angle of the Mandible: an Experimental and Comparative Study 55

JAMES W. MONSON AND WILLIAM J. L. FELTS. Transplantation Studies of Factors in Skeletal Organogenesis. II. The Response of the Immature Mouse Humerus to Longitudinal Compressive Force 63

RICHARD F. SHAW. The Effect of Polygamy and Infanticide on the Sex Ratio 79

Book Reviews

- VIKEN SASSOUNI. The Face: In Five Dimensions 85
- BRUCE WALLACE AND TH. DOBZHANSKY. Radiation, Genes, and Man 87
- REIDER SELMER-OLSEN. An Odontometrical Study on the Norwegian Lapps 88
- W. E. LE GROS CLARK. The Antecedents of Man 88

Proceedings of the Twenty-Ninth Annual Meeting of The American Association of Physical Anthropologists 91

No. 2 JUNE 1961

WILLIAM MONTAGNA, KENJIRO YASUDA AND RICHARD A. ELLIS. The Skin of Primates. V. The Skin of the Black Lemur (*Lemur macaco*) ... 115

P. VENNING. Radiological Studies of Variation in Ossification of the Foot. III. Cone Shaped Epiphyses of the Proximal Phalanges 131

P. VENNING. Radiological Studies of Variation in Ossification of the Foot. IV. The Length and Growth of Bones of the Foot in Relation to Morphology 137

MILTON ALEXANDER, ROBERT S. ZEIGEN AND IRVIN EMANUEL. Anthropometric Data Presented in Three-Dimensional Forms 147

CAREY D. MILLER. Stature and Build of Hawaii-Born Youth of Japanese Ancestry 159

BARBARA HONEYMAN HEATH, CARL E. HOPKINS AND CAREY D. MILLER. Physiques of Hawaii-Born Young Men and Women of Japanese Ancestry, Compared with College Men and Women of the United States and England 173

RICHARD G. SNYDER. Manned Space Flight Vehicles and the Physical Anthropologist 185

B. S. BLUMBERG, ELIZABETH W. IKIN AND A. E. MOURANT. The Blood Groups of the Pastoral Fulani of Northern Nigeria and the Yoruba of Western Nigeria 195

GABRIEL WARD LASKER AND F. GAYNOR EVANS. Age, Environment and Migration: Further Anthropometric Findings on Migrant and Non-Migrant Mexicans 203

Book Reviews:

R. H. OSBORNE AND F. V. DE GEORGE. Genetic Basis of Morphological Variation 213
GABRIEL WARD LASKER. The Processes of Ongoing Human Evolution 215
D. F. ROBERTS AND G. A. HARRISON. Natural Selection in Human Populations 215
GARRETT HARDIN. Nature and Man's Fate 217
ANNE ROE AND GEORGE G. SIMPSON. Behavior and Evolution 218
JOHN T. ROBINSON. The Dentition of the Australopithecinae 219
H. HARRIS. Human Biochemical Genetics 220

No. 3 SEPTEMBER 1961

INDERA P. SINGH AND DARSHAN SINGH. The Study of ABO Blood Groups of Sainis of Punjab 223

BERTRAM S. KRAUS. The Western Apache: Some Anthropometric Observations 227

FRANCIS E. JOHNSTON AND CHARLES E. SNOW. The Reassessment of the Age and Sex of the Indian Knoll Skeletal Population: Demographic and Methodological Aspects 237

T. LEWIN, B. TENGROTH AND B. BERGKVIST. A Photographic Method for Craniometrics 245

RONALD K. WETHERINGTON. A Note on the Fusion of the Lunate and Triquetral Centers 251

M. LAYRISSE, Z. LAYRISSE AND J. WILBERT. The Blood Group Antigens in Goajiro Indians 255

VIRGINIA B. KNOTT. Size and Form of the Dental Arches in Children with Good Occlusion Studied Longitudinally from Age 9 Years to Late Adolescence 263

LAUREL RAYMOND SETTY. The Distribution of Chest Hair in Caucasoid Males 285

S. T. CHAN, K. S. F. CHANG AND F. K. HSU. Growth and Skeletal Maturation of Chinese Children in Hong Kong 289

Melvin L. Moss. Rotation of the Otic Capsule in Bipedal Rats 301
W. K. Chagula. The Liver of the Mountain Gorilla (*Gorilla gorilla beringei*) 309

No. 4 DECEMBER 1961

Jørgen Balslev Jørgensen, Erling Paridon and Flemming Quaade. The Correlation Between External Cranial Volume and Brain Volume 317
David Hewitt and Roy M. Acheson. Some Aspects of Skeletal Development Through Adolescence. I. Variations in the Rate and Pattern of Skeletal Maturation at Puberty 321
David Hewitt and Roy M. Acheson. Some Aspects of Skeletal Development Through Adolescence. II. The Inter-Relationship Between Skeletal Maturation and Growth at Puberty 333
Donald G. Vernall. A Study of the Size and Shape of Cross Sections of Hair from Four Races of Men 345
B. L. Hanna. Comparative Spectrophotometric Absorption of the Pigments from Non-Red Human Hair 351
Stanley M. Garn, Christabel G. Rohmann and Donald K. Wallace. Association Between Alternate Sequences of Hand-Wrist Ossification 361
Stanley M. Garn, Christabel G. Rohmann and Benjamin Apfelbaum. Complete Epiphyseal Union of the Hand 365
E. C. B. Hall-Craggs. The Blood Vessels of the Heart of Gorilla Gorilla beringei 373
Kalevi Koski, Johannes Haataja and Marja Lappalainen. Skeletal Development of Hand and Wrist in Finnish Children 379
M. Lewis, J. A. Hildes, H. Kaita and B. Chown. The Blood Groups of the Kutchin Indians at Old Crow, Yukon Territory 383
Francisco M. Salzano. Studies on the Caingang Indians. III. Blood Groups 391
Viking Fund Medalist for 1960 (Sherwood L. Washburn) by William Walter Greulich 405

Book Reviews:

G. W. Lasker. The Evolution of Man. *Reviewed by* D. F. Roberts .. 409
Genetics and Twentieth Century Darwinism. *Cold Spring Harbor Symposia on Quantitative Biology. Reviewed by* Richard H. Osborne 409
Index to Volume 19 413

The Skin of Primates

III. THE SKIN OF THE SLOW LORIS (NYCTICEBUS COUCANG)[1]

WILLIAM MONTAGNA, KENJIRO YASUDA AND RICHARD A. ELLIS
Arnold Biological Laboratory, Brown University, Providence, Rhode Island

The slow loris, *Nycticebus coucang*, is the larger of the two forms of oriental Lorisidae. Its skin has many details in common with that of the smaller *Loris tardigradus* (Montagna and Ellis, '60), but several important differences warrant a thorough description.

MATERIAL AND METHODS

We have used the skin of two adult males and three females, about 15 inches long, and each weighing about three pounds. The animals thrived in captivity, eating fresh fruits, vegetables, cereals mixed with milk, dog food, and live young mice. Some of the animals remained healthy on this diet for more than one year. Pieces of skin were removed from all regions of the body while the animals were anesthetized. For histological studies paraffin sections of skin fixed in Helly's fluid and 10% neutral formalin were stained with Giemsa and with 0.05% toluidin blue buffered to pH 4.5. Similar sections were treated with the PAS technique for the demonstration of glycogen and other carbohydrates; control sections were digested with saliva, which removes glycogen but not other carbohydrates, before they were treated with the PAS technique. Phosphorylase (Takeuchi and Kuriaki, '55), succinic dehydrogenase (Farber and Louviere, '56), cytochrome oxidase (Burstone, '59), and monoamine oxidase (Glenner et al., '57) were demonstrated in frozen sections of unfixed tissues. Other enzymes were studied in frozen sections of tissues fixed for 4 hours in 10% chilled, unbuffered neutral formalin: (1) alkaline phosphatase using both the cobalt sulfide technique and a variety of azo-dye techniques (Gomori, '52); (2) acid phosphatase (Rutenburg and Seligman, '55); (3) nonspecific esterases, alpha naphthol esterase, and naphthol AS esterase (Pearse, '53); (4) Tween esterase (Stowell and Lee, '50); (5) acetylcholinesterase and butyrylcholinesterase (Montagna and Ellis, '57). All of these techniques have been standardized and they give repeatable results.

GENERAL OBSERVATIONS

The slow loris, being entirely nocturnal, spends the day rolled up like a ball with its head tucked against its belly. It is a quarrelsome animal, and when disturbed emits purring, bird-like chatter and grunts, while snapping at the intruder. When forcibly handled it screams like a rabbit in distress.

Although we do not know where our animals were captured, their markings correspond to those of *Nycticebus coucang bengalensis* (see Hill, '53) (figs. 1, 2). *Nycticebus* has a thick, greyish pelage of dense, soft, underhair, and sparse, coarse overhairs. On the flexor surface of the arm and forearm and on the lower lumbar and sacral regions, the base of the hair is encrusted with a yellowish substance. Although sinus hair follicles are numerous over the upper lip, the cheeks, brows, and even the eyelids, the vibrissae are short and inconspicuous (fig. 2). Males and females have 4 nipples, the anterior pair at the level of the last rib. There is practically no tail; a short stump is folded ventrally like a triangular lid over the dorsal part of the anus (figs. 3, 4).

An area of skin about two inches long and one-quarter to one-half inch in width over the anticubital region is palpably

---

[1] This work was supported by grants from the United States Public Health Service (RG-2125-C11), the National Science Foundation (G-4392), the Colgate-Palmolive Company and Chesebrough-Pond's, Inc.

much thicker than that around it. The hairs over these surfaces are usually damp and matted together with a yellowish, viscid substance which has a fetid, fruity odor reminiscent of citrus fruits. Although the entire skin is odorous, we have confirmed Hill's ('56) observation that the odor is most pungent on the anticubital skin. This skin contains large aggregates of glands and is similar to the *brachial organ* of the slender loris (Montagna and Ellis, '60). In the excised skin (fig. 5), the underside of the brachial organ is a pebbly, greyish-pink mass of glands, two to three millimeters thick.

Shaved animals have a whitish skin. There is some dark pigmentation over the scrotum and on the perianal regions only.

The epidermis

Except over the lips, muzzle, scrotum, and genital regions, the epidermis is relatively thin. Over the general body the incomplete, single-layered granular layer consists of a few flat cells with very small keratohyalin granules, separating the two or three-layered malpighian layer from the corneal layer. The granular layer is thicker and more distinct in the epidermis around the orifices of the pilary canals, and wherever the epidermis is thicker. The corneal layer remains about the same thickness over the body.

The epidermis is nearly free of melanocytes. A few are found in groups in the epidermis of the scrotum and the face. The epidermis of the palms and soles is thick and its underside is grooved by deep ridges to which are attached at evenly spaced intervals the ducts of the sweat glands. In spite of its great thickness, the epidermis has weak strata granulosum and lucidum; the stratum corneum is thick. A few melanocytes are found only at the bottom of the epidermal ridges around the attachment of the duct of the sweat glands.

The epidermis has the same general attributes as that of the potto and the slender loris (Montagna and Ellis, '59, '60). The malpighian layer contains succinic dehydrogenase and monoamine oxidase; cytochrome oxidase is found only in the thick epidermis of the lips and genital regions, the palms and soles, and the volar side of the digits; some enzyme reaction is also found in the epidermis around the pilary canals. Phosphorylase activity is present throughout the malpighian layer and is most concentrated where the epidermis is thickest. The malpighian layer has moderate acid phosphatase activity and abundant nonspecific esterase; it has no alkaline phosphatase. A few capillaries, the endothelium of which has strong alkaline phosphatase activity, make an occasional shallow loop under the epidermis between the hair island (figs. 9, 10). Capillaries are more numerous underneath the epidermis of the palms and soles (fig. 6). Small, barely visible nerves, reactive for acetylcholinesterase from the dermal net, rise up to the epidermis (fig. 18) and seem to penetrate between its cells. This is particularly clear in the epidermis of the face, the lips, and the genital areas.

The dermis

The thick dermis consists almost entirely of a reticular layer of collagenous fibers. Around the few blood vessels and the cutaneous appendages the dermis consists of areolar connective tissue containing fibroblasts, mast cells, and delicate collagenous fibers. The dermis is veneered in thin successive layers in which the collagenous fibers are oriented at right angles to one another. The direction of the fibers is alternately parallel and perpendicular to the surface. A few elastic fibers are found in the lower level of the dermis. Dermal melanocytes are rare even in the scrotum, where the surface epidermis has more melanin than elsewhere.

Blood vessels in the dermis are largely limited to those which go to the groups of hair follicles. Single arterioles rise from the subcutaneous tissue to the upper dermis, branch into capillaries, and go toward the groups of hair follicles. Rarely, a capillary loop is seen under the epidermis. The endothelium of these vessels is reactive for alkaline phosphatase. We have studied only those nerves that contain monoamine oxidase and/or cholinesterase. Large myelinated and unmyelinated nerve trunks from the subcutaneous tissue rise up to the level of the sebaceous glands, where they form a loose network iented parallel to the surface of the skin. he myelinated fibers all contain mono- mine oxidase, acetylcholinesterase, and ome butyrylcholinesterase. The nerves in ie dermal net contain traces of mono- mine oxidase and acetylcholinesterase but o butyrylcholinesterase (fig. 11).

In the palms and soles large nerve unks from the hypodermis ascend to the pper dermis where they branch in the orm of inverted arcades under the epi- ermis. Many of these nerves end in nall, round Meissner corpuscles (fig. 7). he large nerve trunks and the Meissner orpuscles contain both acetylcholinester- se and butyrylcholinesterase; the small erve arcades and delicate free terminals ontain only acetylcholinesterase.

The skin of the scrotum and prepuce nd that of the vulva is very richly sup- lied with nerves which are also strongly eactive for acetylcholinesterase. In the iid-dermis the nerves form large, tangled iasses, from which nerves rise up toward ie surface and terminate under the epi- ermis.

The pilary system

Six to 20 hair follicles grow in islands iat are surrounded by glabrous skin figs. 8, 10, 13, 14). The hair islands are omposed of follicles with a small diam- ter that produce the woolly underhairs nd a few larger follicles that produce uard hairs. The hair islands on the dorsal irfaces have more large follicles than iose on the ventral surfaces. The follicles i each group grow very close together, ut each opens separately to the surface. here is one sweat gland associated with ach hair group. Within the same group ie follicles may be in different states of ctivity; some are growing, while others re quiescent. The hair follicles on the iuzzle and lips grow singly and are not ustered in groups. The pilary canal of ll the hair follicles is very short.

The quiescent follicles are short and xtend only about midway into the dermis figs. 10, 17). The acuminate club hair surrounded by a thin epithelial capsule vo layers thick; from the base of the ipsule, a short, cone-shaped hair germ xtends to the dermal papilla. Active fol- cles are very thin and long, and the elongated bulb is burrowed deep in the hypodermal fat. The topography of the hair follicle is like that of *Loris tardigradus* (Montagna and Ellis, '60).

The distribution of metachromatic substances and that of glycogen in growing follicles is similar to that in the follicles of other mammals. Although the quiescent follicles of the other primates we have studied contain appreciable amounts of glycogen, those of *Nycticebus* contain practically none.

The distribution of various enzymes in hair follicles is similar to that found in the potto and the loris (Montagna and Ellis, '59, '60). Quiescent hair follicles have small amounts of succinic dehydrogenase, monoamine oxidase, and cytochrome oxidase; they abound in nonspecific esterases and phosphorylase. The dermal papilla has strong alkaline phosphatase, whether the follicles are active or quiescent. Active follicles have quantitatively larger amounts of all these enzymes.

Arterioles in the subcutaneous fat rise to the upper dermis and send capillaries to the upper part of hair follicles. A single, very loose, capillary network encircles the entire hair group with only some branches penetrating the group to encircle some individual follicle (figs. 9, 10). The hair follicles which grow singly over the lips are supplied with blood vessels at the level of the sebaceous glands, but there are no vessels around the lower part of the follicles.

Nerves arising from the dermal network penetrate the islands of hairs and send branches to each follicle (fig. 11). The terminal nerve forms a small collar at the base of the infundibulum, just below the entrance of the sebaceous glands (fig. 12). One or more nerves go to the sweat gland. The nerves running toward the hair follicles contain only acetylcholinesterase; the nerve collars around each follicle contain mostly butyrylcholinesterase. Those hair follicles in the lips which resemble sinus hairs are all very richly supplied with cholinesterase-containing nerves (fig. 12). An even richer nerve plexus is found around the true sinus follicles.

The sebaceous glands

The sebaceous glands of quiescent hair follicles are usually small and have no duct; those of active follicles are larger and have a short excretory duct. The sebaceous glands on the lips, muzzle, brachial organ, the eyelids, and the skin of the genital organs are larger than those elsewhere on the body. Regardless of their location or size, the glands have similar cytological and histochemical properties.

The glands contain no glycogen, although traces may be found in the cells of their ducts. All cells have intense reactions for succinic dehydrogenase, monoamine oxidase, and cytochrome oxidase (fig. 17). They have only traces of phosphorylase activity (fig. 15). All sebaceous cells, whether differentiated or not, are rich in nonspecific-α-naphthol esterases and AS esterases; they contain no Tween esterases. The glands have scant acid phosphatase and no alkaline phosphatase. The meibomian glands and the other large sebaceous glands in the eyelids all have properties identical with those of the glands elsewhere on the body, except that the glands of the eyelids, and particularly the meibomian glands, are surrounded by numerous nerves which are reactive for acetylcholinesterase (Montagna and Ellis, '59a) (fig. 3).

The sudoriparous glands

One simple tubular, variably coiled apocrine gland is found with each hair group. A dilated, variably coiled secretory coil extends to the lower part of the dermis; the long and very narrow duct runs parallel to the hair follicles and opens to the surface separately in a conical dilatation (figs. 15, 16). The glands are larger in the skin of the cheeks, lips, eyelids, and genital areas.

The duct consists of two layers of flat cuboidal cells. The cells of the secretory tubule are columnar or cuboidal and may have cytoplasmic blebs protruding into the lumen from the free edge of the cells.

The cytoplasm of the secretory cells contains fine, sparse, basophil granules and small yellow pigment granules in the basal two thirds; in the luminal part it is practically achromic. A layer of very large myoepithelial cells surrounds the secretory epithelium. The secretory cells also contain some PAS-positive, nonglycogen granules. The colloid in the lumen is
moderately PAS-reactive. The myoepith
lial cells have small amounts of glycoge
but the secretory cells do not. The bas
cells of the ducts always contain som
glycogen.

The secretory segment in intensely r
active for succinic dehydrogenase, mon
amine oxidase, and cytochrome oxida
(fig. 17); the duct shows only sma
amounts of these enzymes. Both the du
and the secretory coil of the glands a
strongly reactive for phosphorylase (fi
16). The glands have alkaline phosph
tase in the myoepithelium and in the bas
part of the secretory epithelial cells; i
some glands the reaction is restricted
the luminal part of the cells. The secr
tory cells have small amounts of ac
phosphatase; they contain practically n
alpha naphthol esterase, but relative
large amounts of AS esterase and Twee
esterase.

From the dermal network a nerve go
to each gland and forms a loose lattic
around its secretory coil, but not aroun
its duct (fig. 18). Some nerves may e
tend laterally from the glands to termina
in candelabra-like arcades underneath th
epidermis. This is particularly pronounce
in the skin of the lips and that of th
genital and perianal regions. These nerve
contain acetylcholinesterase but no but
rylcholinesterase.

In the brachial organ the large gland
are separated only by very thin septa o
loose, areolar tissue. The thin, long duc
of these glands converge toward the sha
low pilary canals at the surface of the ski
and open into them (fig. 19); some duc
open singly to the surface. The histochem
ical properties of the glands of the brachi
organs are similar to those of the othe
glands. They abound in succinic dehydro
genase, monoamine oxidase, cytochrom
oxidase, and phosphorylase (fig. 20); the
have practically no alpha naphthol este
ase, some AS esterase, and a great deal o
Tween esterase (fig. 21). There is ver
little acid phosphatase but much alkalin
phosphatase (fig. 22). The endotheliu
of the few capillaries around the glands
reactive for alkaline phosphatase (fig. 22

The glands are surrounded by numerou
nerves that contain acetylcholinesteras
(fig. 23). The excretory ducts rarely hav

ch nerve fibers around them. A few olinesterase reactive nerve fibers are so found around the pilary canals of the llicles, into which the excretory ducts of e glands of the brachial organ open.

The glands in the volar surfaces of the nds, feet, and digits grossly resemble th apocrine and eccrine glands (figs. , 25, 26). A thick, loosely coiled secre- y segment opens abruptly into a very in and straight excretory duct; the ter- inal part of the duct within the epidermis coiled.

The cells of the secretory coil seem to heaped over one another to form two yers of cells. The large myoepithelial lls, which have an achromic cytoplasm, rm the basal layer. The cells facing the men are pyriform and have a basophil toplasm; they are all alike and corre- ond to neither the dark nor the clear lls of the glands of other mammals. The toplasm of these cells has a delicate ppling of glycogen and coarse PAS-posi- e granules above the nucleus. The cells the ducts, which are very small, contain nall amounts of glycogen.

The glands abound in succinic dehydro- nase, monoamine oxidase, cytochrome idase (fig. 24), and phosphorylase (fig.). They are weakly reactive for ester- es and acid phosphatase, and rich in kaline phosphatase (fig. 26). A few osphatase reactive capillaries surround e glands (fig. 26). The glomerate por- n of the gland is surrounded by coarse rves that contain acetylcholinesterase g. 27). These do not form an intricate t around the coils, as do those around e glands of the brachial organ.

The responses of the sweat glands to pharmacological tests

To test whether the various sweat glands spond to cholinergic or to adrenergic muli, we injected mecholyl and adre- lin intradermally in several parts of the dy. Two-and-one-half milligrams of cholyl injected into the dermis of the achial organ and into that in several ner parts of the body, including the lms and soles, has no effect upon the eat glands, even though the animal ivated and lacrimated profusely. In- tions of 5.0 mg of mecholyl in the palms d soles caused a very slight amount of sweating. Epinephrine diluted 1:10,000 was injected into the skin of the brachial organ and caused an immediate profuse secretion. Injections of epinephrine elsewhere on the body resulted in the appearance of sparse, small beads of secretion on the surface. Epinephrine had no effect upon the glands of the palms and soles. Thus, the glands on the volar surfaces of the hands and feet are not activated by adrenergic stimuli and only slightly activated by cholinergic ones. The body glands and those of the brachial organ are readily activated by adrenergic stimuli.

DISCUSSION

The skin of *Nycticebus* is similar in some respects to that of the other two lorisoids we have studied, *Loris* and *Perodicticus*. The practical absence of a papillary body in the dermis, the scant blood supply, the aggregation of variable numbers of hair follicles into large islands, the presence over the body of only apocrine glands, and the poor differentiation of the glands of the volar surfaces of hands and feet into eccrine types suggest that the skin is poorly specialized.

All of the sweat glands of *Nycticebus* resemble apocrine glands, even those on the volar surfaces of the hands and feet. The apocrine glands, like those of *Loris* (Montagna and Ellis, '60), contain phosphorylase, the presence of which had hitherto been considered to be a characteristic feature of the eccrine glands of primates. These apocrine glands are also surrounded by nerves which contain specific cholinesterase, another feature which before had been considered peculiar to eccrine glands. The embodiment in these organs of some of the peculiarities of both eccrine and apocrine glands must represent as unspecialized state.

The glands on the volar surfaces of the pes and manus have peculiar features of their own. Phylogenetically, these are the most ancient eccrine sweat glands (Kuno, '56). Yet, they look like both apocrine and eccrine glands. Their secretory epithelium is composed of one type of cell which shows no differentiation into dark and clear cells, such as those found in the eccrine glands of higher forms (Montagna, '56). Whereas eccrine glands characteristically contain much glycogen, those of

Nycticebus contain only traces of it. Other eccrine glands usually contain little alkaline phosphatase, but these are rich in it (fig. 26). Eccrine sweat glands are easily stimulated to secrete with injections of acetylcholine, but in *Nycticebus* this drug has practically no effect. Thus, specialization in the glands of the palms and soles into eccrine types has not progressed very far in *Nycticebus*, and the glands seem to have little secretory function.

Many of the characteristics of the skin of *Nycticebus* are those of an unspecialized type, but the elaborate development of the brachial organ must be a highly specialized feature. The apocrine glands in this region are very large and invested by myriads of nerves; the ducts of several glands open into a common dilated pilary canal. Stimulation with epinephrine evokes copious discharge of fetid secretion product. The glands of the brachial organ are different from those glands found in the other regions of the skin; the brachial organ, then, is a signal feature in the specialization of the skin of *Nycticebus* and the *Loris*.

The presence of large amounts of specific cholinesterase in nerves has been assumed to indicate cholinergic nerves. However, the apocrine glands of the brachial organ and of the rest of the body of this animal, which are surrounded by such nerves, do not respond to acetylcholine, and they respond to epinephrine. The glands of the palms, soles, and digits do not seem to respond to either of these agents. Thus, either there has been a misinterpretation of facts in the past or the nerves of *Nycticebus* are different from those in other animals. The presence of nerves around glandular tissue is not always easy to explain. The meibomian glands of these animals, as well as those of many others, including man, are surrounded by nerves that contain cholinesterase (Montagna and Ellis, '59a). It is not likely that holocrine glands could be stimulated by nerve impulses, since their secretion must be synthesized slowly within the cells and become available as the final secretory product only when the cells that have formed it die and break up. Perhaps the nerves around the apocrine glands are not really secretory, but sensory nerves, and the glands may be stimulated by humoral agents, as they are i the horse (Evans, '57; Evans et al., '57 Thus, one must not assume too readi that mere spacial intimacy of nerves a structure necessarily denotes a neur visceral relationship.

The only other point we wish to discu is the innervation of hair follicles. Th nerves that penetrate each hair isla send branches to every hair follicle, a each nerve is attached to a compact ner ous collar around the base of the i fundibulum. It is significant that this co lar contains pseudocholinesterase, wher as the nerves attached to them contai only specific cholinesterase. This is ide tical with what one finds in the variou end-organs in glabrous skin, in which th nerves have specific cholinesterase a the end-organs proper contain pseudoch linesterase. Thus, in agreement wit Winkelmann ('60) we consider the coll of nerves an end-organ, which we wi henceforth call the "hair follicle en organ."

SUMMARY

1. The skin of *Nycticebus* resembles i many respects that of the *Loris*. Its derm has practically no papillary body; it h a scant blood supply; the epidermis is ve thin; the hair follicles are arranged large islands; the sweat glands over th general body skin are all of the apocrin type; the sweat glands on the volar surfa of the hands and feet are poorly diffe entiated into eccrine glands. All swe glands seem to have some features whic are common to both the apocrine and e crine types.

2. Specialization has not progressed f in the skin of *Nycticebus;* the concentr tion of large apocrine sweat glands, th "brachial organ," however, is a specializ tion peculiar only to *Nycticebus* and *Loris*.

3. The histochemical properties of th skin of *Nycticebus* resemble those of th skin of *Loris*. The apocrine glands abou in phosphorylase, although heretofore th enzyme has been found only in the eccri sweat glands of other primates and in th apocrine glands of *Loris* only. Apocri glands are all surrounded by nerves whic contain cholinesterase; this is a peculiari of the glands of *Nycticebus*.

4. Even though apocrine glands are all rrounded by nerves which contain spe- fic cholinesterase, acetylcholine fails to imulate the glands. They are stimulated y very small amounts of epinephrine.

5. The glands on the volar surfaces of e hands and feet resemble apocrine ore than they do eccrine glands. They spond to neither acetylcholine nor epi- ephrine, although large quantities of ace- lcholine cause a minimal amount of cretion.

6. The skin of *Nycticebus* appears to be ry primitive, and specialization of the arious cutaneous appendages has not rogressed very far. Although eccrine and pocrine sweat glands have specialized long very different paths in higher pri- ates, they may have arisen from a com- on form, which may have resembled the pocrine glands of *Nycticebus*.

LITERATURE CITED

urstone, M. S. 1959 New histochemical techniques for the demonstration of tissue oxidase (cytochrome oxidase). J. Histochem. Cytochem., *7:* 112–122.

vans, C. L. 1957 Sweating in relation to sympathetic innervation. Brit. Med. Bull., *13:* 197–201.

vans, C. L., A. M. Nisbet and K. A. Ross 1957 A histological study of the sweat glands of normal and dry-coated horses. J. Comp. Pathol. Therapy, *67:* 397–405.

arber, E., and C. D. Louviere 1956 Histochemical localization of specific oxidative enzymes. IV. Soluble oxidation-reduction dyes as aids in the histochemical localization of oxidative enzymes with tetrazolium salts. J. Histochem. Cytochem., *4:* 347–356.

lenner, G. G., H. J. Burtner and G. W. Brown, Jr. 1957 The histochemical demonstration of monoamine oxidase activity by tetrazolium salts. Ibid., *5:* 591–600.

Gomori, G. 1952 Microscopic Histochemistry. Principles and Practice. The University of Chicago Press, Chicago, Illinois.

Hill, W. C. O. 1953 Primates, Comparative Anatomy and Taxonomy. I. Strepsirhini. Interscience Publishers, New York, pp. 175–194.

——— 1956 Body odour in lorises. Proc. Zool. Soc. London, *127:* 580.

Kuno, Y. 1956 Human Perspiration. Charles C Thomas Co., Springfield, Illinois.

Montagna, W. 1956 The Structure and Function of Skin. Academic Press, Inc., New York, New York.

Montagna, W., and R. A. Ellis 1957 Histology and cytochemistry of human skin. XII. Cholinesterases in the hair follicles of the scalp. J. Inv. Derm., *29:* 151–157.

——— 1959 The skin of primates. I. The skin of the potto (*Perodicticus potto*). Am. J. Phys. Anthrop., *17:* 137–162.

——— 1959a Cholinergic innervation of the meibomian glands. Anat. Rec., *135:* 121–128.

——— 1960 The skin of primates. II. The skin of the slender loris (*Loris tardigradus*). Am. J. Phys. Anthrop., *18:* 19–44.

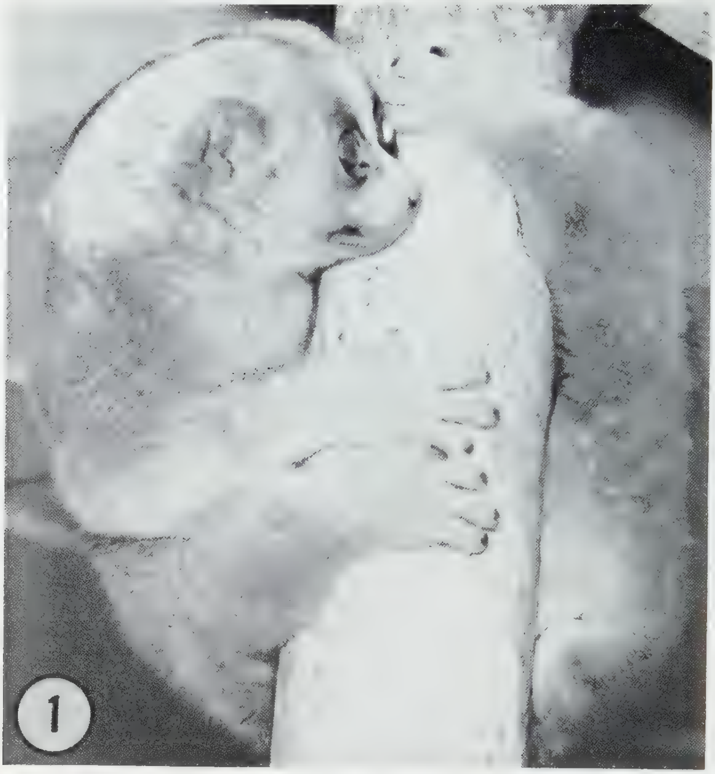
Pearse, A. G. E. 1953 Histochemistry, Theoretical and Applied. Little, Brown and Co., Boston, Massachusetts.

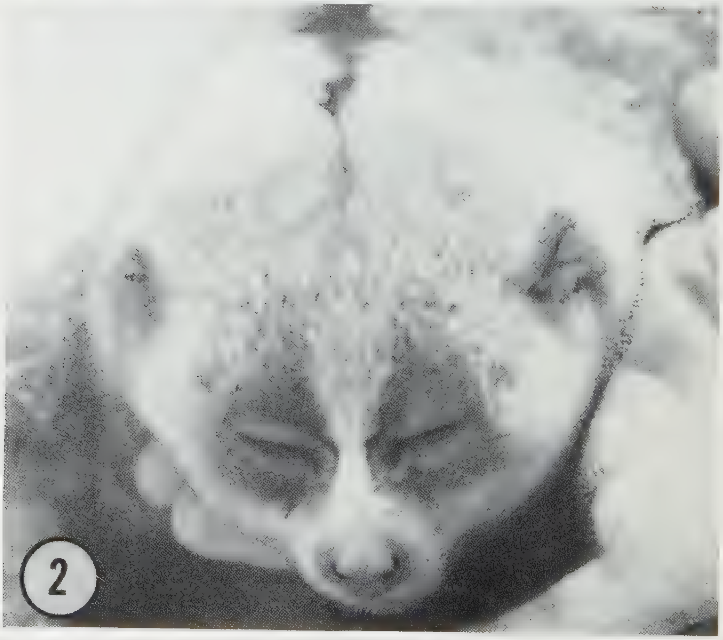
Rutenburg, A. M., and A. M. Seligman 1955 The histochemical demonstration of acid phosphatase by a post-incubation coupling technique. J. Histochem. Cytochem., *3:* 455–470.

Stowell, R. E., and C. S. Lee 1950 Histochemical studies of mouse liver after single feeding of carbon tetracholoride. Arch. Pathol., *50:* 519–537.

Takeuchi, T., and H. Kuriaki 1955 Histochemical demonstration of phosphorylase in animal tissues. J. Histochem. Cytochem., *3:* 153–160.

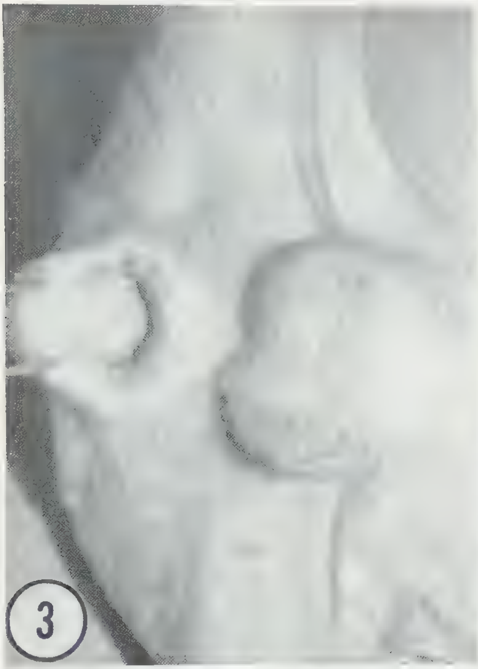
Winkelmann, R. K. 1960 Similarities in cutaneous nerve end-organs. In: Advances in Biology of Skin. vol. I. Cutaneous Innervation. W. Montagna, ed. Pergamon Press, Inc., Oxford, England, chap. II.

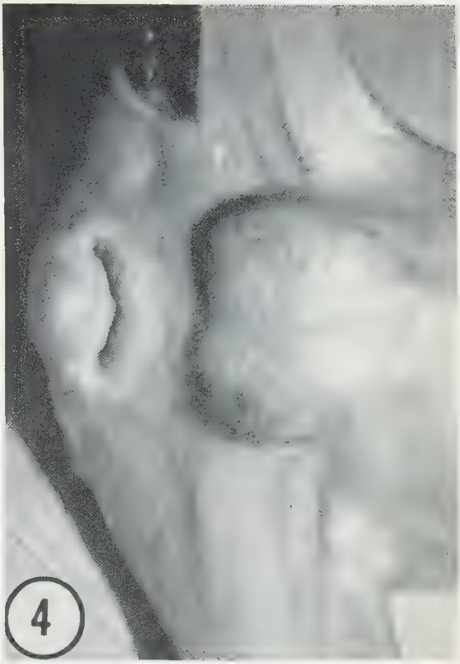


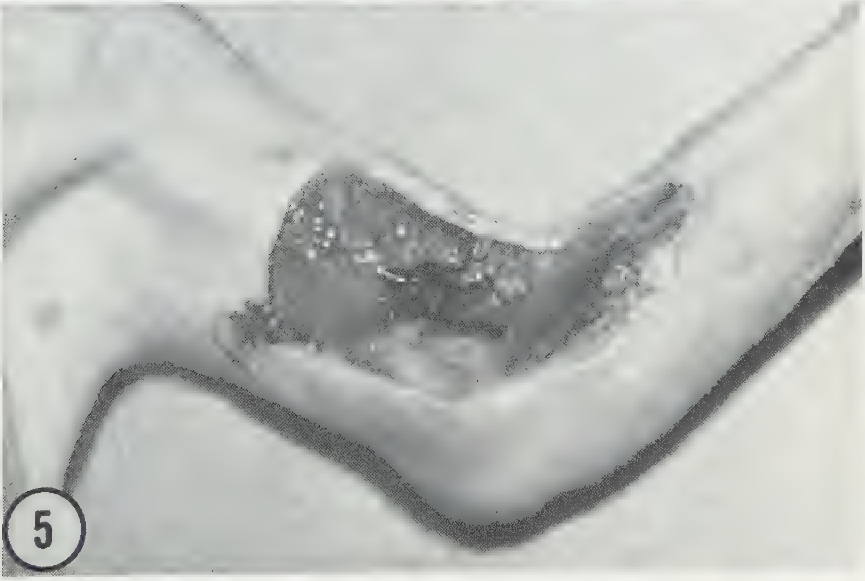


1 Adult female *Nycticebus* photographed in the animal room.

2 Detail of the head of the animal in figure 1, showing that the dorsal dark line does not extend to the head.







3 The stump of the tail of a male animal pulled back.

4 The tail is in its normal position.

5 The left arm of a male *Nycticebus* with the skin area of the brachial organ removed.

PLATE 3

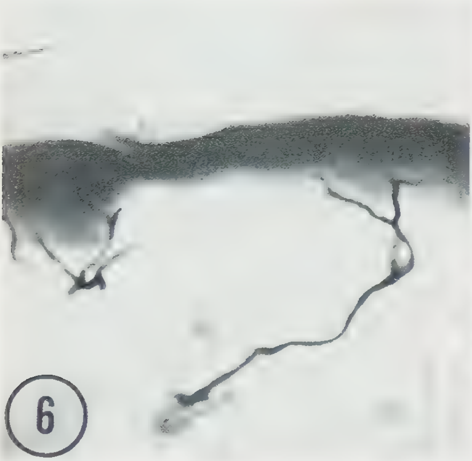
EXPLANATION OF FIGURES

6 Skin from the palm, treated with Gomori's alkaline phosphatase technique. The capillaries underneath the epidermis are strongly reactive.

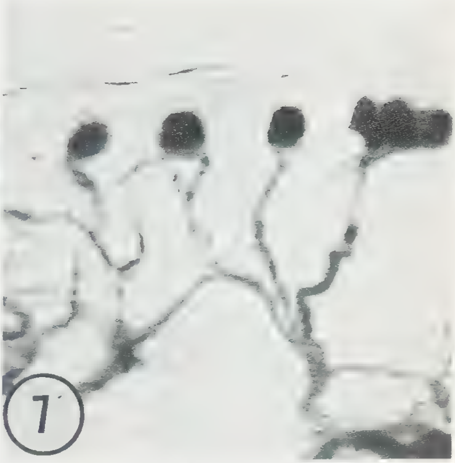
7 Skin from the volar surface of the hallux. Nerves and end-organs (Meissner corpuscles) show abundant cholinesterase, the end-organs contain both specific and nonspecific cholinesterase.

8 Skin from the lumbar region of the back showing succinic dehydrogenase. The section has been cut parallel to the surface of the skin to show the configuration of a single hair island, which contains 26 follicles. The arrow points to the duct of a sweat gland, usually roughly in the center of the hair group. The hiatus between the upper and the lower portion of the group is a characteristic feature of the skin of these animals, and each hair island is usually divided into three or 4 subgroups.

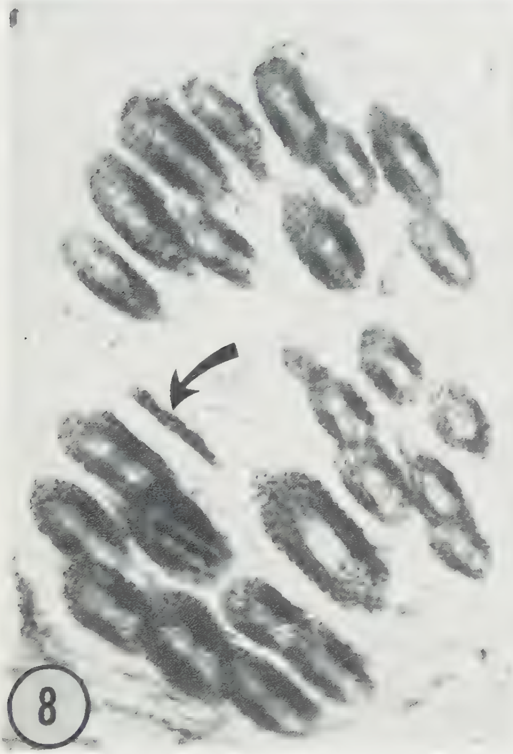
9 Skin from the scapular region of the back showing a small island of hair follicles surrounded by a single capillary loop, strongly reactive for alkaline phosphatase (technique of Gomori).



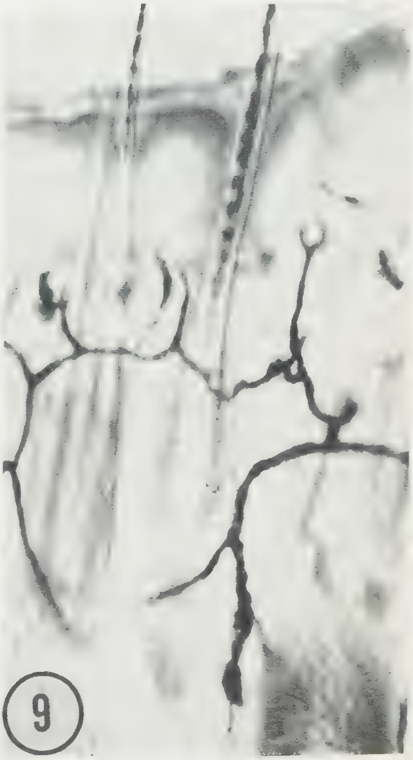
6



7



8



9

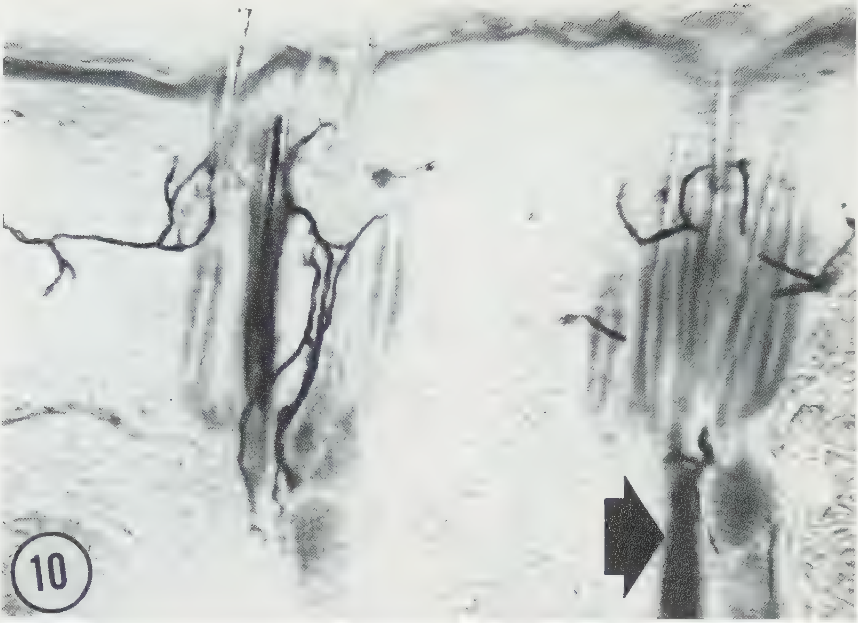
PLATE 4

EXPLANATION OF FIGURES

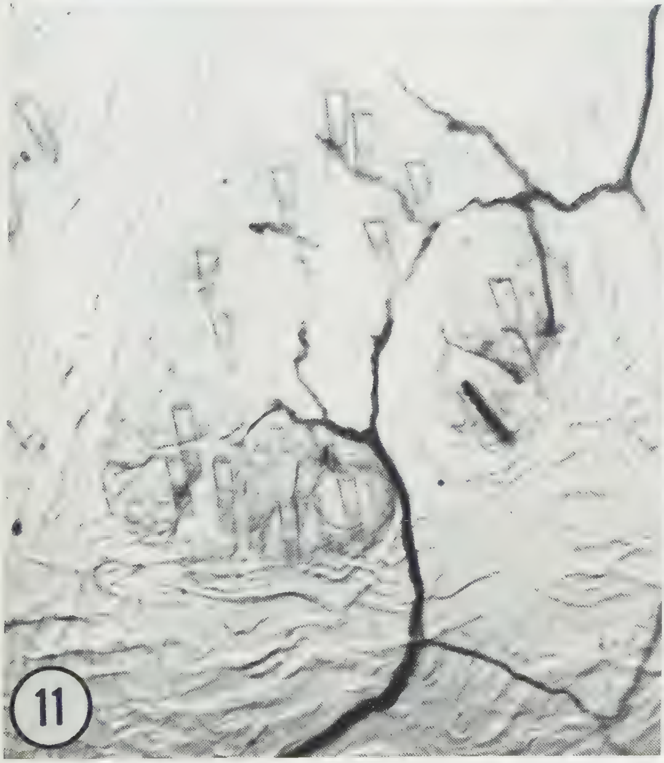
10 Capillary loops around two hair islands in the skin from the lumbar region of the back, treated with Gomori's technique for alkaline phosphatase. The arrow points to an active follicle in a hair group which is otherwise composed of quiescent follicles.

11 Specific cholinesterase in the nerves of the skin of the back. Unstained frozen section, cut parallel to the surface. Two nerves are seen going to the hair island where each divides giving off one nerve to each follicle.

12 Two transverse sections of hair follicles in the skin of the lip. The arrows point to the hair follicle end-organs, which contain both specific and nonspecific cholinesterase.



10



11

12

PLATE 5

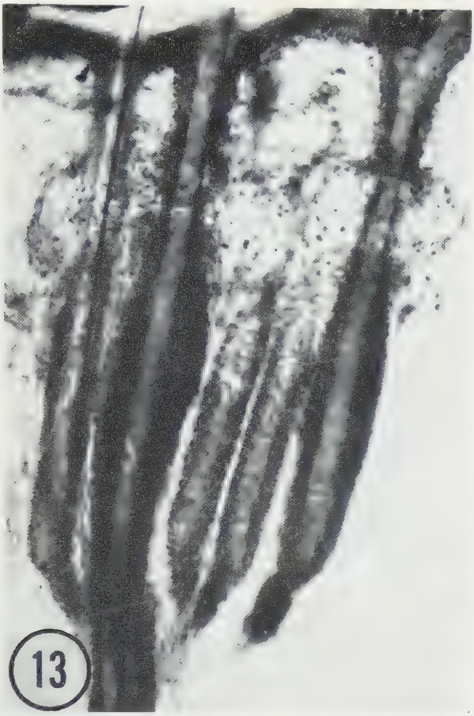
EXPLANATION OF FIGURES

13 Succinic dehydrogenase in the skin from the scapular region of the back, showing only a part of a hair island. One hair follicle is active, the others are quiescent. Enzyme activity is strong in the epithelial capsule around the hair club and in the outer root sheath of the active hair follicle.

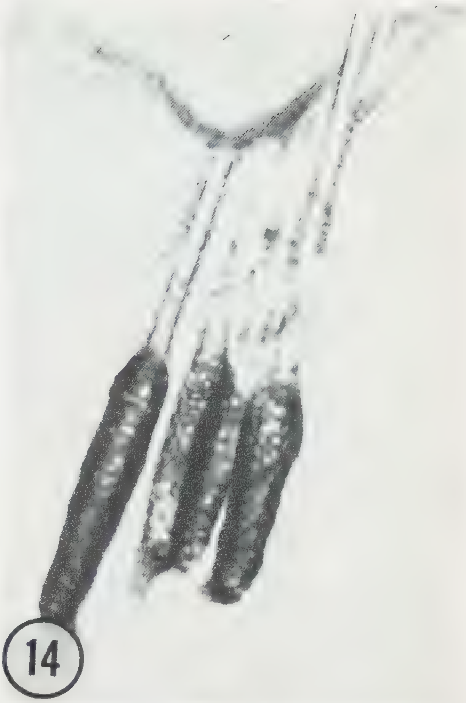
14 Phosphorylase activity in the epithelial capsule of 4 quiescent hair follicles from the skin of the back.

15 Phosphorylase activity in the skin from the back. On the right of the quiescent hair follicle is a sweat gland with the arrow pointing to the abrupt transition between the secretory portion below and the excretory duct above. The duct flares out slightly when it reaches the epidermis.

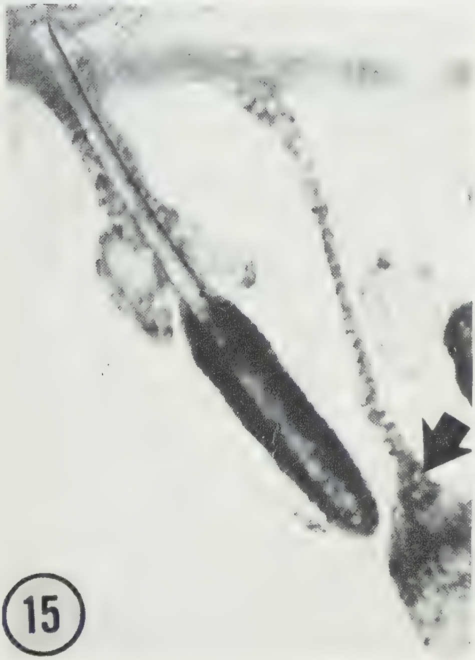
16 Skin from the arm showing phosphorylase activity in a sweat gland and in hair follicles. The arrow points to the transition between the gland and the duct.



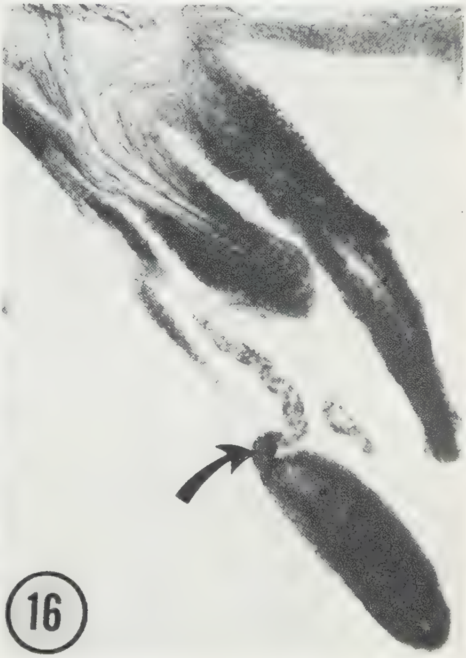
13



14



15



16

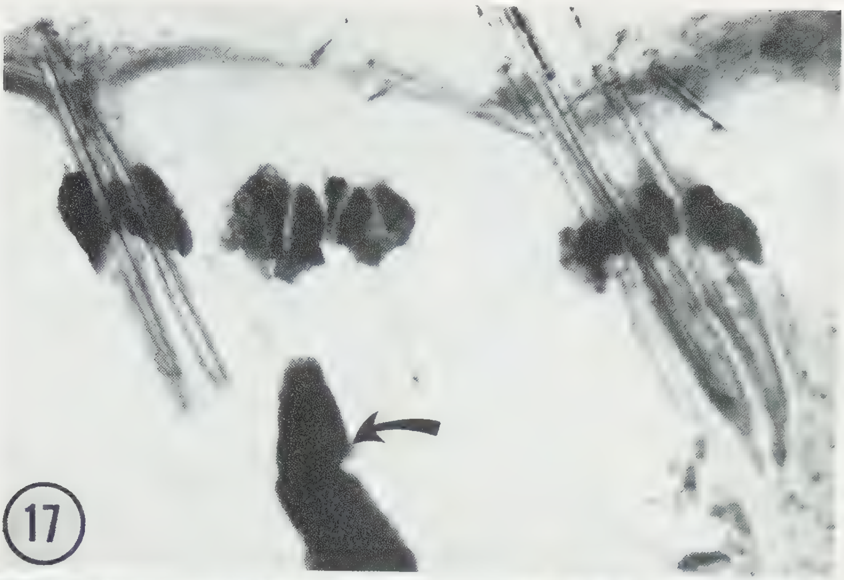
PLATE 6

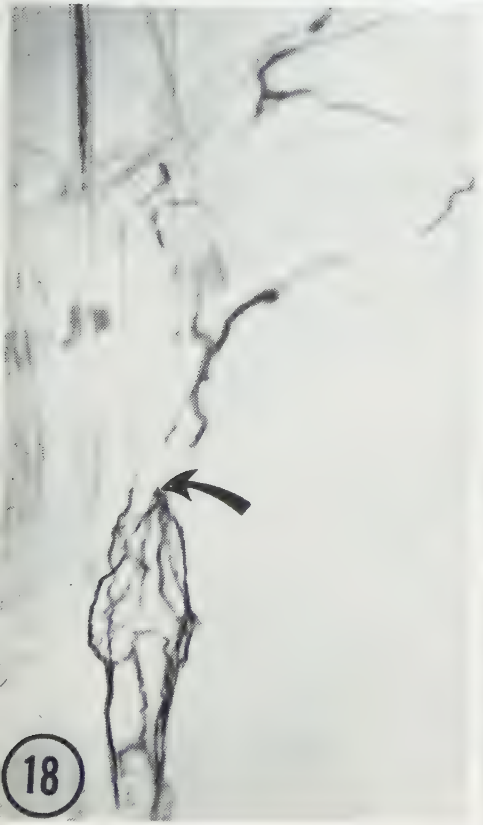
EXPLANATION OF FIGURES

17 Cytochrome oxidase in the skin from the back. Enzyme activity is intense in the sebaceous glands and in the sweat gland (arrow). There is some enzyme activity in the epithelial capsules of hair follicles and very small amounts of it in the hair germ.

18 Skin from the lumbar region of the back showing specific cholinesterase in the nerves around the apocrine sweat gland below the arrow. Above the arrow the nerves branch, sending one loop around the hair follicle, not seen very clearly, and another loop underneath the epidermis.

19 Succinic dehydrogenase in the ducts of the glands of the brachial organ as they open into the dilated pilary canals.


17


18

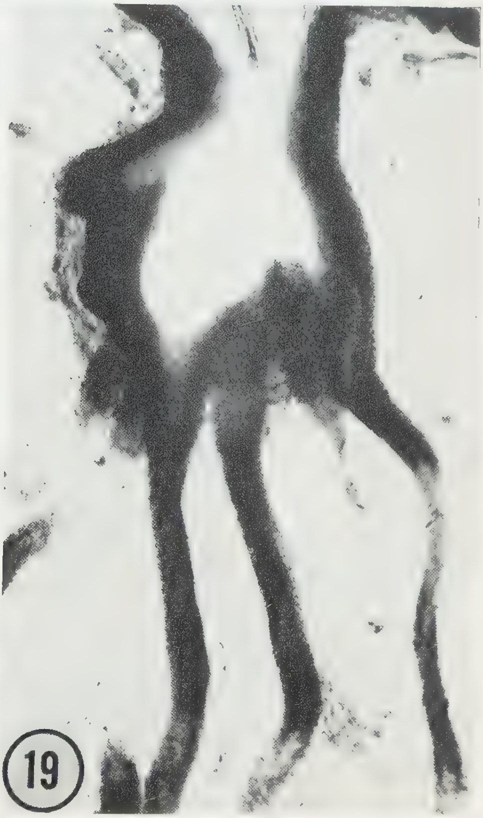

19

PLATE 7

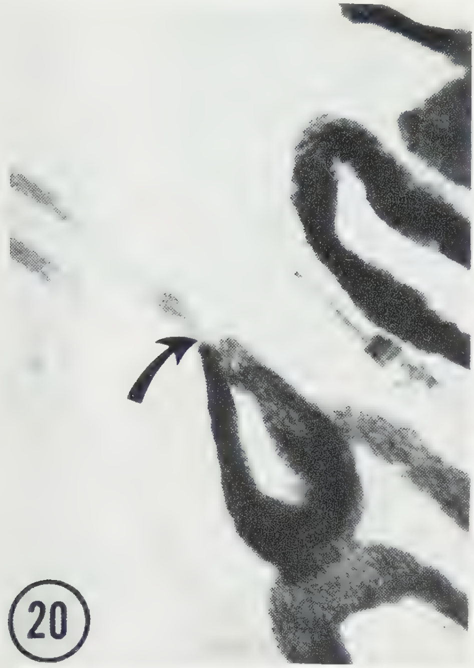
EXPLANATION OF FIGURES

20 Segments of glands from the brachial organ showing intense phosphorylase activity. The arrow points at the transition between the secretory coil, below the arrow, and the duct above the arrow. The duct is more reactive than it appears in this figure.

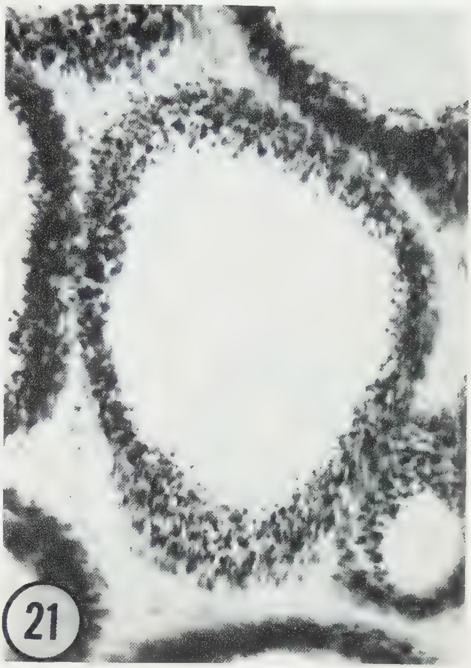
21 Tween esterase activity in the glands of the brachial organ.

22 Alkaline phosphatase in the glands of the brachial organ. Both the myoepithelial cells and the secretory cells are intensely reactive. The arrow points to the capillaries which surround the secretory coil.

23 Rich plexus of nerves contaning specific cholinesterase, around the glands of the brachial organ.



20



21

22

23

PLATE 8

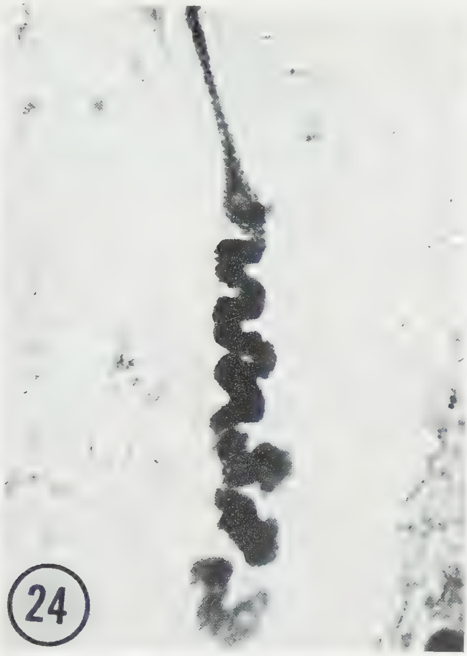
EXPLANATION OF FIGURES

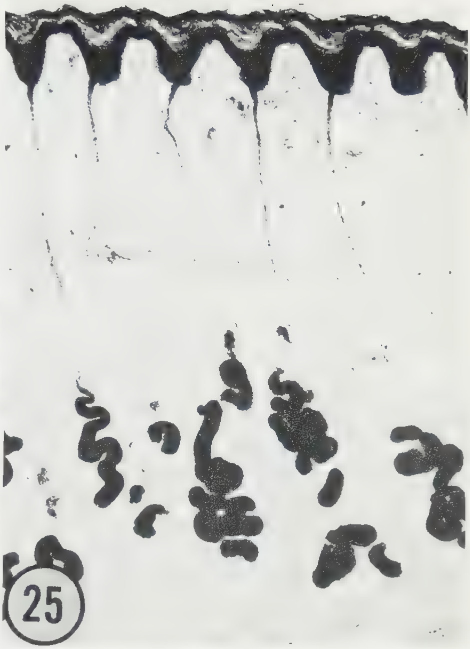
24 Cytochrome oxidase in a gland from the volar surface of a digit; both the excretory duct in the upper portion of the figure and the coiled secretory tubule in the lower portion are reactive.

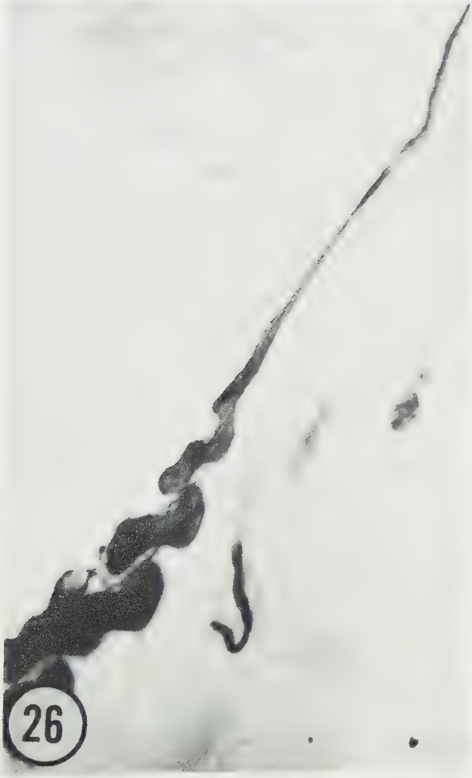
25 Phosphorylase activity in the palm. There is strong enzyme activity in the rete ridges of the epidermis and in the sweat glands. This preparation shows some glands in their entirety.

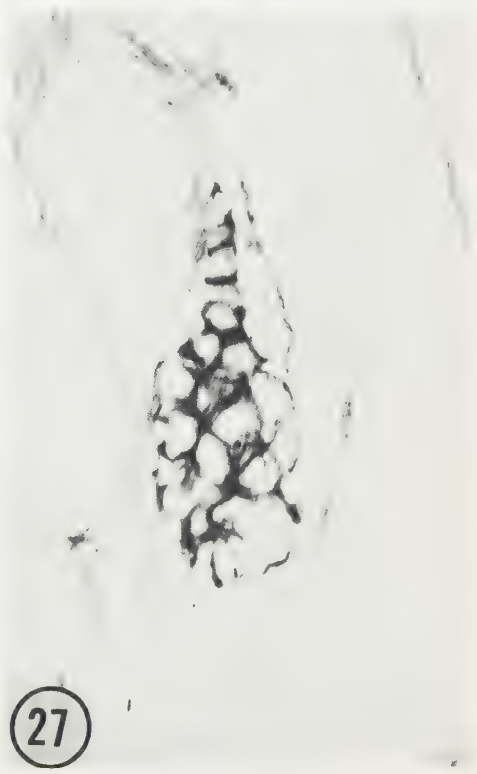
26 Gland from the volar portion of a digit, showing alkaline phosphatase activity, both in the secretory coil and in the duct. A few capillaries, rich in alkaline phosphatase, can be seen around the gland.

27 Secretory coil of the gland from the volar surface of a digit, completely surrounded by nerves rich in specific cholinesterase.


24


25


26


27

ne Skin of Primates

. THE SKIN OF THE LESSER BUSHBABY (GALAGO SENEGALENSIS)[1]

KENJIRO YASUDA, TSUYOSHI AOKI AND WILLIAM MONTAGNA
Arnold Biological Laboratory, Brown University,
Providence, Rhode Island

The skin of the lesser bushbaby *(Galago negalensis)* is relatively uncomplicated d resembles more the skin of some ro- nts than that of primates.

MATERIALS AND METHODS

These observations were made on the in of one adult male and two females. ecimens of skin from the various regions the body were removed while the ani- als were anesthetized. Paraffin sections tissues, fixed in Helly's fluid and in % formalin, were stained with (a) to- idin blue, buffered to pH 5.0, (b) with matoxylin and eosin, and (c) with the S technique; control sections for the S technique were previously digested th saliva. Frozen sections of fresh tis- es were treated with the method of keuchi and Kuriaki ('55) for the dem- stration of phosphorylase, that of Glen- r et al. ('57) for monoamine oxidase, at of Farber and Louviere ('56) for ccinic dehydrogenase, and that of Bur- one ('60a, b) for cytochrome oxidase. ozen sections of tissue fixed in chilled % formalin for 4 hours were treated the demonstration of alkaline and acid osphatases (Gomori, '52), alpha naph- ol esterase (Gomori, '52), naphthol AS etate esterase (Pearse, '60), aminopep- ase (Burstone and Folk, '56), and cho- esterases (Montagna and Ellis, '57).

DESCRIPTION

The lesser galago, or bushbaby, is one the smaller members of the family ligidae. The thick, soft, woolly fur is rk gray, with a delicate brown suffusion the underparts. The animals are en- ely nocturnal, sleeping during the day huddled in a box. Our animals thrived for two years on a diet of succulent fruits and live young mice. When killed, the animals were fat and had a rich pelage. They did not utter a sound the entire time they were in captivity, even when handled. In order to study active hair follicles, we plucked the hairs from a large area of the skin of the lumbosacral region. The naked skin there was at first pink, became gray after one week, and nearly black after three weeks. New hairs emerged on the surface 4 weeks after plucking (see Chase, '55 for the effect of plucking).

The epidermis

The epidermis of the general body surface is thin. The malpighian layer is three or 4 cells deep, the basal cells having distinct cytoplasmic denticles that grow into the dermis. The cells of the discontinuous, one cell deep stratum granulosum, contain sparse keratohyalin granules that stain with basic dyes. The stratum corneum, 8 to 10 layers thick, is about the same total thickness as the malpighian layer. The epidermis of the palms, soles, and volar surface of the digits is like that of the other Lorisidae (Montagna and Ellis, '59, '60; Montagna et al., '60). Except over the friction areas, the epidermis has a flat underside. Dendritic melanocytes are found only in the tips of the epidermal ridges in the scrotum, the vulva, and in the palms and soles; elsewhere the epidermis has no melanocytes. The cells of the basal layer rest upon a PAS-reactive basement membrane which follows the outlines of the basal denticles.

---

[1] This work was supported by grants from the United States Public Health Service RG-2125 (C10), Colgate-Palmolive Company, and Chesebrough-Pond's, Inc.

Except in that of the scrotum, where glycogen may occasionally be found in the cells of the spinous layer of the surface fissures, the epidermis contains neither glycogen nor other PAS-reactive, nonglycogen material.

There is no phosphorylase reactivity in the epidermis of the general body surface. In the palms and soles a slight reaction is concentrated largely in the epidermal ridges. Cytochrome oxidase is concentrated in the deeper layers, and the intensity of distribution differs from region to region. The distribution of succinic dehydrogenase and monoamine oxidase is similar to that in the epidermis of other primates. Aminopeptidase reaction is weak; it is stronger in the thicker epidermis of the scrotum and vulva and in that of the palms and soles. The epidermis has no alkaline phosphatase, except in dendritic cells scattered among the epidermal cells of the palms and soles (fig. 1), and to a lesser extent in the epidermis elsewhere (cf. Montagna and Ellis, '59). A weak to moderate reaction for acid phosphatase throughout the malpighian layer is more pronounced in the granular layer of the epidermis of the palms and soles. There is nothing unique about the distribution of naphthol AS esterase and tween esterase. With few exceptions there are no nerve fibers ending in the epidermis that contain cholinesterases. Some fibers are found in the thick epidermis of the scrotum or vulva, and in that of the perianal region and of the lips. The encapsulated endings will be described under the dermis.

The dermis

The dermis has practically no papillary body, and superficial arcades of capillaries are largely absent, except in the palms and soles, the perianal region, and the lips. The endothelium of these few capillaries stains deeply for alkaline phosphatase, as in most other primates. Dermal melanocytes are found only in the perianal region, the scrotum, the eyelids and ears; fibroblasts are numerous. The reticular body is a many-ply structure in which the collagenous fibers are oriented alternately parallel and perpendicular to the surface Except on the underparts of the body, the skin has a thick panniculus carnosus below the fatty layer and is particularly thick in the scalp and the back.

Nerve branches from under the epidermis and from hair follicles join a loose net of cholinesterase-rich nerve fibers in the superficial part of the dermis. The "hair follicle end-organs" and the nerves around the glands are described with these organs. Small, cholinesterase positive end organs, are found under the epidermis at the mucocutaneous junctions. Very small round Meissner corpuscles, in the upper parts, and large Pacinian corpuscles, in the deep fat, are numerous in the palms and soles. Throughout the skin of the scrotum and the vulva are tangled masses of nerves (fig. 2). The nerves that emerge from all of these end-organs, and the various nerve nets described have strong reactions for both specific and pseudocholinesterase. Some of the nerves also contain monoamine oxidase.

The pilary system

Unlike the pelage of other lorisoids which grows in large islands of variable numbers, that of the galago grows in small groups of three to 6 follicles (fig. 3). In the lips and face the groups are ill-defined

Hair follicles must grow more or less at once. With few exceptions, only those follicles, the club hairs from which had been plucked several weeks before, were active. The animals were fat and healthy and had a rich pelage; the inactivity of the follicles, then, cannot be attributed to poor nutrition. Hairs and hair follicles resemble those of the other lorisoids we have studied; the hairs have a thin cortex and a large medulla interrupted by evenly spaced hair cells. Quiescent follicles are shallow and extend at most to the middle of the dermis. They have a long pilary canal into which open the very small sebaceous glands. The acuminate hair club is surrounded by a thin epithelial sac two cells thick; from this a short hair germ is in contact with the small dermal papilla Only the follicles in the tail have large arrectores pilorum muscles; elsewhere the muscles are very poorly developed. The very long active follicles extend to the

y layer and often the bulb abuts against
panniculus carnosus.
ctive hair follicles contain a little cyto-
ome oxidase in the outer root sheath
ve the bulb and in the cells of the
rix; quiescent follicles have a trace of
ction in the epithelial capsule and the
r germ. Succinic dehydrogenase, mono-
ine oxidase, and phosphorylase are dis-
uted as in the hair follicles of other
mates. Alkaline phosphatase activity is
nd primarily in the dermal papilla of
h active and quiescent follicles and in
ollar of tissue around the pilary canal
mediately below the entrance of the
aceous glands (fig. 4). Very few blood
sels, with an alkaline phosphatase reac-
endothelium, surround the follicles.
d phosphatase, alpha naphthol esterase,
l naphthol AS esterase activity have no
tinctive localization and are like those
other lorisoids. Some delicate nerve
ers around the hair follicles are reactive
acetylthiocholinesterase. These fibers
not form a network around the follicle
emerge from the curious plate-like, or
ninar, collar around the pilary canal
ich is mentioned above. The collar is
ensely reactive for both acetyl- and
yrylthiocholinesterase and must be a
ir follicle end-organ" (figs. 5, 6).

The sebaceous glands

The small sebaceous glands open di-
tly into the pilary canal. Larger and
re complex glands are found in the
otum, vulva, perianal region, and lips.
ne of the glands are well vascularized.
sebaceous glands in the scrotum and
ianal region contain small amounts
nonglycogen, PAS material; the others
not. All glands have a strong cyto-
ome oxidase, succinic dehydrogenase,
l monoamine oxidase activity, but prac-
lly no phosphorylase activity. Seba-
us glands have moderate to strong
ha naphthol esterase activity and
hthol AS esterase activity, the largest
nds having the strongest reaction. There
some aminopeptidase activity in the
ipheral cells, no alkaline phosphatase
. 4), and a small amount of acid
sphatase. In the meibomian glands the
um abounds in alkaline phosphatase
. 7). Sebaceous glands, except for the meibomian glands, have no nerves around them which contain cholinesterases.

The sweat glands of the general body surface

One simple, slightly coiled apocrine sweat gland is associated with each hair group. A narrow, straight duct, with a terminal ampulliform dilatation, opens directly onto the surface of the skin, near the opening of a pilary canal. The secretory part of the gland extends to the deeper portion of the dermis. The glands are largest in the lips, the eyelids, and the perianal region (fig. 8). The secretory segment is lined with a simple, columnar epithelium, and the duct consists of two layers of low cuboidal cells. The cytoplasm of the secretory cells stains readily with basic dyes; it contains variable amounts of a yellow or orange pigment, diffuse amounts of glycogen (fig. 8), and nonpigmented granules which are PAS-positive. The glands abound in cytochrome oxidase, succinic dehydrogenase, and monoamine oxidase. Phosphorylase activity, strong in the duct, is present only in the myoepithelial cells of the secretory segment. The cuticle of the ducts always contains alkaline phosphatase (fig. 4), but the secretory coil shows very little reaction. The glands of the lips, eyelids, vulva, and perianal region have variable amounts of enzyme in the myoepithelial cells and in the basal portion of the secretory cells (fig. 9). Very few alkaline phosphatase-rich capillaries surround the secretory coils. The glands have scant to moderate amounts of acid phosphatase, aminopeptidase, alpha naphthol esterase (fig. 10) and naphthol AS esterase only in the secretory portion. There are no nerves containing cholinesterases around the secretory segment; those in the perianal region and vulva and those in the eyelids, however, have nerves around them that react for both acetylthiocholinesterase and butyrylthiocholinesterase (fig. 11).

The glands on the volar surface of the hands and feet

Sweat glands, sparse on the palms and soles, are numerous on the balls of the digit. From the thick, coiled secretory segment deep in the fatty pad, a narrow duct takes a straight path to the epidermis where it forms a slightly coiled intraepidermal segment (fig. 13).

The cells of the secretory segment rest upon a layer of large myoepithelial cells, under which is a thick basement membrane. The smaller secretory cells are shoved toward the lumen, and the larger ones remain at the base. Since the small cells stain deeply with basic dyes, and the larger ones do not, the cells correspond to the dark and clear cells respectively. Indications of intercellular canaliculi can be seen only between the clear cells.

The clear cells are rich in glycogen, but the dark cells have little or none (fig. 12). Cytochrome oxidase, succinic dehydrogenase, monoamine oxidase, and phosphorylase, heavily concentrated in the secretory epithelium, are practically absent from the duct. The secretory segment has small amounts of alpha naphthol esterase, naphthol AS esterase, tween esterase, acid phosphatase, and aminopeptidase; the duct has practically none. The basal portions of the secretory cells and the myoepithelial cells have strong alkaline phosphatase activity (fig. 13), but very few arterioles and capillaries with an alkaline phosphatase-rich epithelium surround the glands. Nerve fibers, with strong concentrations of acetylcholinesterase and some butyrylthiocholinesterase, surround the coils of the secretory segment.

DISCUSSION

The skin of the bushbaby, in some respects, resembles that of other lorisoids and particularly that of the potto (Montagna and Ellis, '59, '60; Montagna et al., '60). Noteworthy among these similarities are the curious alkaline phosphatase-rich dendritic cells in the epidermis, previously found only in the potto.

The general architecture and the properties of the dermis concurs with that of the other lorisoids. The absence of a papillary body and the paucity of cutaneous blood vessels, including those around the appendages, call attention to a relatively undeveloped skin similar to that of laboratory rodents.

The hair follicles grow in smaller groups than those of the potto (Montagna and Ellis, '59). Since nearly all of the follicl
in the three animals we used were quie
cent, these animals may shed their ha
in definite periods. Follicles grow whe
the club hairs are plucked, and the ra
of growth is about one millimeter per da
Thus, both in structure and in rate
growth the follicles resemble those of r
dents. The peculiarity of the follicles
the lesser galago is a well-developed "ha
follicle end-organ" around the pilary can
that is rich in cholinesterases, alkalin
phosphatase, and alpha naphthol esteras
These end-organs resemble the "mamma
ian" end-organs of the sheep and the co
(Winkelmann, '60), which also conta
cholinesterases and alkaline phosphatas
Quiescent hair follicles contain glycoge
and phosphorylase, two features peculi
to primates.

The sebaceous glands have little to di
tinguish them from those of laborato
rodents. Only the glands on the extern
genitalia, perianal region, lips, and eyeli
are well developed; of these the glands c
the scrotum and perianal region contai
traces of PAS-positive, nonglycogen mat
rial, a feature rarely found in other pr
mates.

Over the general body surface, or
apocrine sweat gland grows with each ha
group. The glands, neither well develope
nor unique, resemble those of the pott
Unlike the potto, the galago has no larg
accumulation of apocrine glands near th
genitalia. Most apocrine glands are sma
and probably nonfunctional. Their duc
open free to the surface and not inside
pilary canal. Schiefferdecker ('22), wh
believed that all apocrine glands original
opened inside the pilary canal, propose
that those glands that occasionally ope
directly upon the surface rise up seconda
ily from the pilary canal to the epidermi
Steiner ('26) thought that this shift fro
the pilary canal to the surface was pro
ably caused by the expansion of the ski
surface. Yet, in most mammals the ap
crine glands open more often near th
pilary orifices than inside it. Confusion o
this point has arisen from studies of th
embryos of man, and also those of the o
(Yasuda et al., '57), in which the gland
develop as secondary buds of the pilar
canal. The ducts of the apocrine gland

f nearly all the primitive primates we ave studied open directly to the surface, uggesting that the association of sweat lands with the pilary canal may be a econdary, rather than a primary event. 'he apocrine glands of the galago are mall and the cells contain some glycogen nd slight amounts of phosphorylase. Oc- asionally, particularly the glands in the yelids, scrotum, vulva, and perianal re- ion, they have nerves around them that ontain cholinesterase. These features and thers described indicate that these glands ave not attained a high degree of differ- ntiation.

The cytological and histochemical char- cteristics of the sweat glands on the alms and soles are like those of eccrine lands. The narrow duct, for instance, raverses a direct path from the secretory oil to the surface.

The skin of the galago, then, resembles hat of the potto. The grouping of hair ollicles is more definite than that in the otto, but the sweat glands of the potto re larger, functional, and probably more dvanced.

SUMMARY

1. The thin epidermis has melanocytes nly in the scrotum and in the palms and oles. Alkaline phosphatase-rich dendritic ells, sown throughout the epidermis, are nore numerous in those of the palms and oles. The histochemistry of the various nzymes in the epidermis is similar to that n the potto.

2. The dermis is composed mostly of a eticular layer. It is free of dendritic mel- nocytes, except in the scrotum. There re few capillaries under the epidermis nd around the cutaneous appendages. ensory end-organs rich in cholinesterases re found in the mucocutaneous junctions, ne palms, soles, vulva, and the perianal kin. Tangled masses of nerves in the ermis of the scrotum, external genitalia, nd perianal region contain specific cho- nesterase.

3. The hair follicles, similar to those of ne potto, grow in small groups of three 6. The structure and the histochemical eatures of the follicles are similar to those f other lorisoids. The follicles are largely uiescent at any particular time, suggesting that they have periods of general shedding of hairs. The only singular feature of the follicles is a ring, or collar-like "hair follicle end-organ" around the upper part of the pilary canal, which is rich in cholinesterases, alkaline phosphatase, and alpha naphthol esterase. The nerves that emerge from the end-organ are reactive for specific cholinesterase.

4. The sebaceous glands are mostly small and not different from those of other lorisoids.

5. Only apocrine sweat glands are found over the general body surface. These small glands open directly to the surface near a pilary canal. The glands are probably not functional, except on the lips, eyelids, perianal skin, vulva, and scrotum. The glands are small, have generalized structural features and histochemical characteristics, and are rudimentary.

6. Eccrine glands, with a long, narrow duct and a slightly coiled secretory segment, are restricted to the palms and soles. The secretory epithelium is barely differentiated into clear and dark cells, and resembles that of the potto.

7. The skin of the lesser galago, like that of the other lorisoids studied, is relatively unspecialized. It has some features which are characteristic of primates, but with the exception of the hair groups, which are more consistent and contain fewer hairs than the groups in the potto and the lorises, the skin is apparently very primitive.

LITERATURE CITED

Burstone, M. S. 1960a New histochemical techniques for the demonstration of tissue oxidase (cytochrome oxidase). J. Histochem. Cytochem., *7:* 112–122.

——— 1960b Histochemical demonstration of cytochrome oxidase with new amine reagents. Ibid., *8:* 63–70.

Burstone, M. S., and J. E. Folk 1956 Histochemical demonstration of aminopeptidase. Ibid., *4:* 217–226.

Chase, H. B. 1955 The physiology and histochemistry of hair growth. J. Soc. Cos. Chem., *6:* 9–14.

Farber, E., and C. D. Louviere 1956 Histochemical localization of specific oxidative enzymes. IV. Soluble oxidation-reduction dyes as aids in the histochemical localization of oxidative enzymes with tetrazolium salts. J. Histochem. Cytochem., *4:* 347–356.

Glenner, G. G., H. J. Burtner and G. W. Brown 1957 The histochemical demonstration of monoamine oxidase activity by tetrazolium salts. Ibid., *5:* 591–600.

Gomori, G. 1952 Microscopic Histochemistry. Principles and Practice. The University of Chicago Press, Chicago, Illinois.

Montagna, W., and R. A. Ellis 1957 Histology and cytochemistry of human skin. XII. Cholinesterase in the hair follicles of the scalp. J. Invest. Dermatol., *29:* 151–157.

——— 1959 The skin of primates. I. The skin of the potto *(Perodicticus potto).* Am. J. Phys. Anthrop., *17:* 137–162.

——— 1960 The skin of primates. II. The skin of the slender loris *(Loris tardigradus).* Ibid., *18:* 19–44.

Montagna, W., K. Yasuda and R. A. Ellis 1960 The skin of primates. III. The skin of the slow loris *(Nycticebus coucang).* Am. J. Phys. Anthropol., *18:* 1–22.

Pearse, A. G. E. 1960 Histochemistry, Theoretical and Applied (Second Edition). Little Brown and Co., Boston, Mass.

Schiefferdecker, P. 1922 Die Hautdrüsen des Menschen und der Säugetiere, ihre biologische und rassenanatomische Bedeutung Sowie Muscularis sexualis. Zoologica, *72:* 1–154.

Steiner, K. 1926 Über die Entwicklung den grossen Schweissdrüsen beim Menschen. Z. Anat. Entwick., *78:* 83–97.

Takeuchi, T., and H. Kuriaki 1955 Histochemical detection of phosphorylase in animal tissues. J. Histochem. Cytochem., *3:* 153–160.

Winkelmann, R. K. 1960 Similarities in cutaneous nerve end-organs. In: Advances in the Biology of Skin. Cutaneous Innervation, W. Montagna, ed., vol. 1. Pergamon Press, Ltd., Oxford, England, chap. II.

Yasuda, K., T. Kaga, T. Goto, T. Kashimura, H. Furusawa and K. Kobayashi 1957 A study on the development of the sweat glands of the cattle embryos. Keio J. Med., *6:* 159–209.

PLATE 1

EXPLANATION OF FIGURES

1 Dendritic, alkaline phosphatase-rich cells in the epidermis of the palm (arrow). Approx. × 50.

2 The dense network of acetylcholinesterase-containing nerve fibers at the apical part of the clitoris. The dark-staining globules at the tip of the clitoris are the mucocutaneous end-organs which contain pseudocholinesterase. Approx. × 50.

3 Surface cut of the epidermis of the lumbosacral region showing hair groups consisting mostly of 4 follicles. Each group is surrounded by nerve fibers that contain acetylcholinesterase. Approx. × 70.

4 Skin from the perianal region stained for alkaline phosphatase. The strongest reaction is in the duct of the apocrine sweat gland above the curved arrow, while the secretory portion has a weak reaction. The "hair follicle end-organs" (straight arrows) have intense reactivity. Approx. × 50.

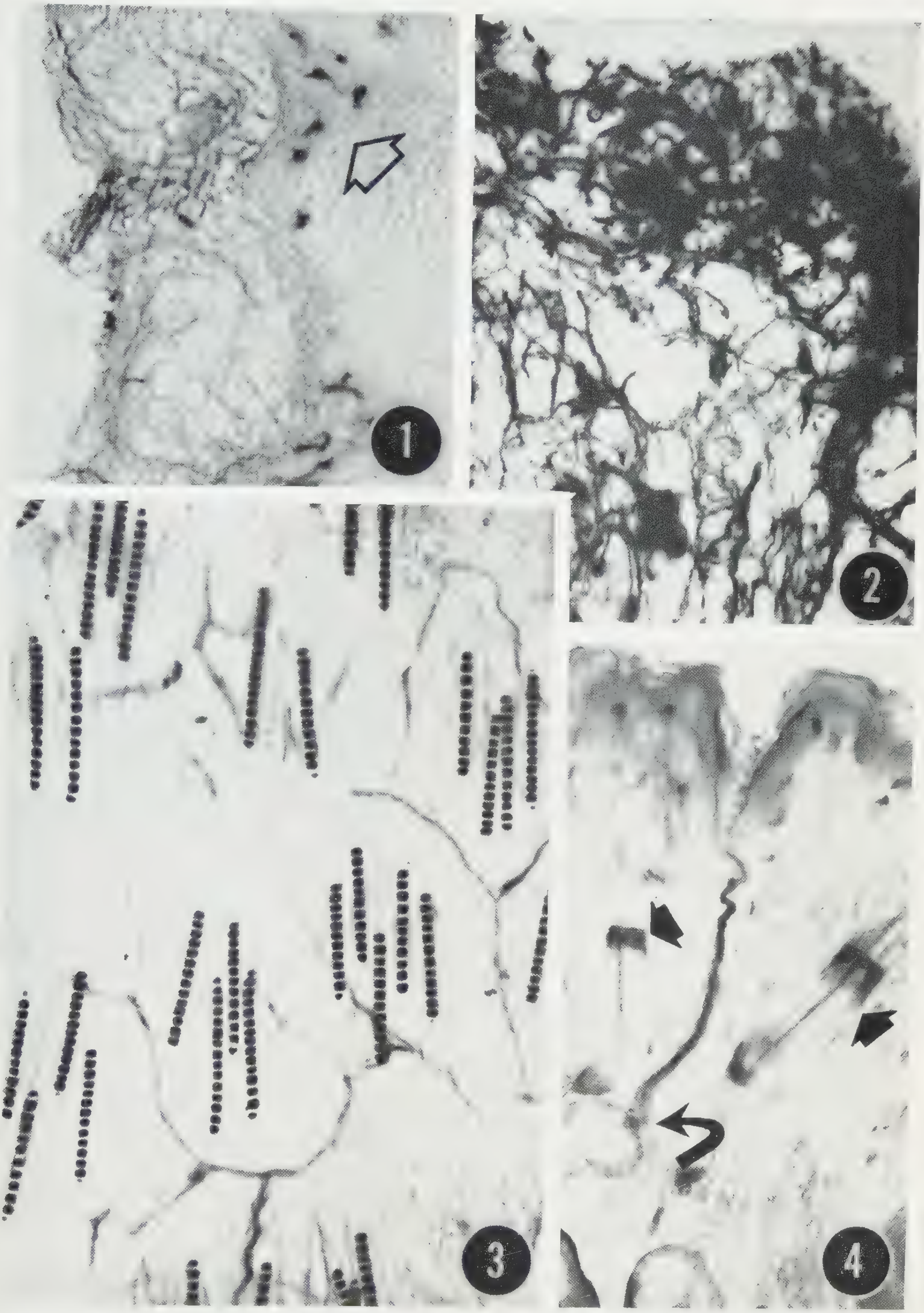

1
2
3
4

PLATE 2

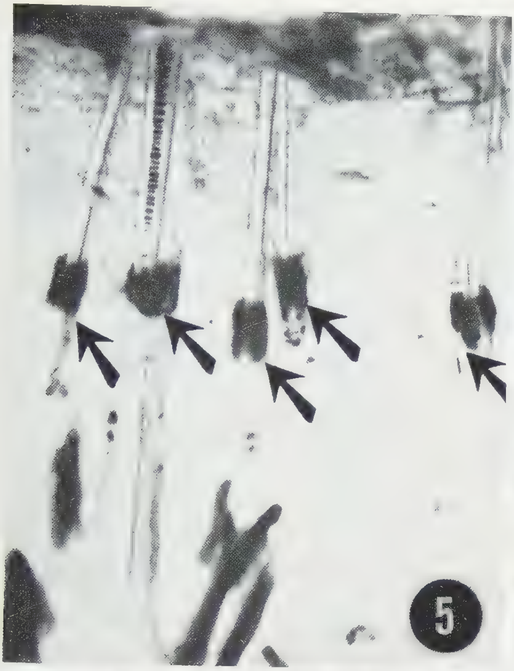
EXPLANATION OF FIGURES

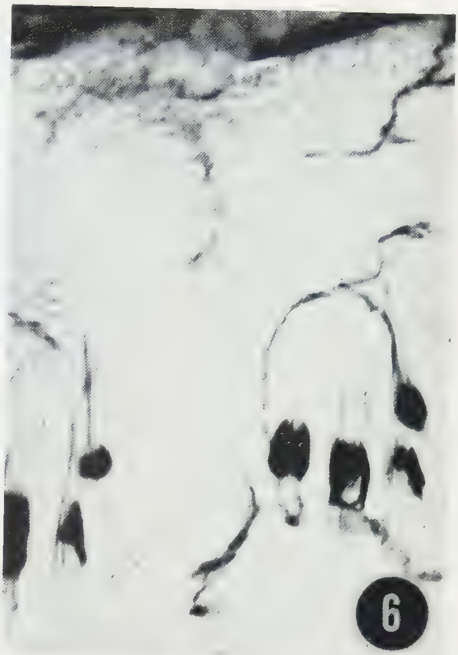
5 Pseudocholinesterase-containing "hair follicle end-organs" around both active and quiescent follicles in the eyelid. Approx. × 50.

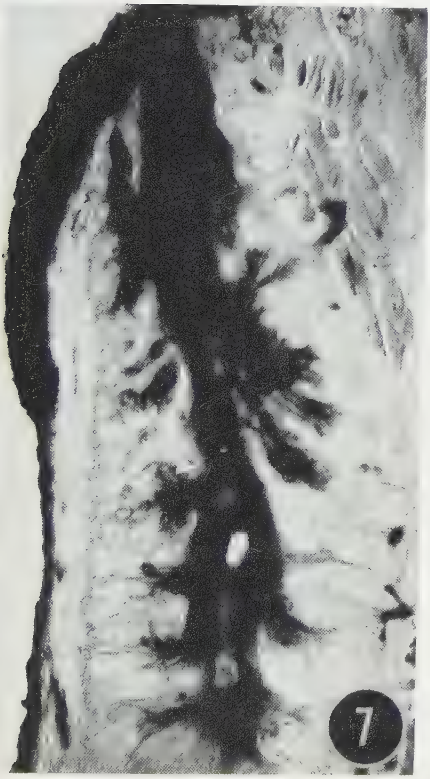
6 "Hair follicle end-organs" in the eyelids showing thin nerve fibers emerging from them. The end-organs contain pseudocholinesterase, the nerves only acetylcholinesterase. Approx. × 50.

7 Alkaline phosphatase activity in the sebum of a meibomian gland. Approx. × 50.

8 Section of a secretory tubule of an apocrine gland in the perianal region, containing a moderate amount of glycogen, homogeneously distributed in the whole cytoplasm. The lumen is filled with saliva resistant, PAS-positive substances. The cytoplasmic protrusions are strongly PAS-reactive and probably contain mucopolysaccharides. Approx. × 200.


5


6


7

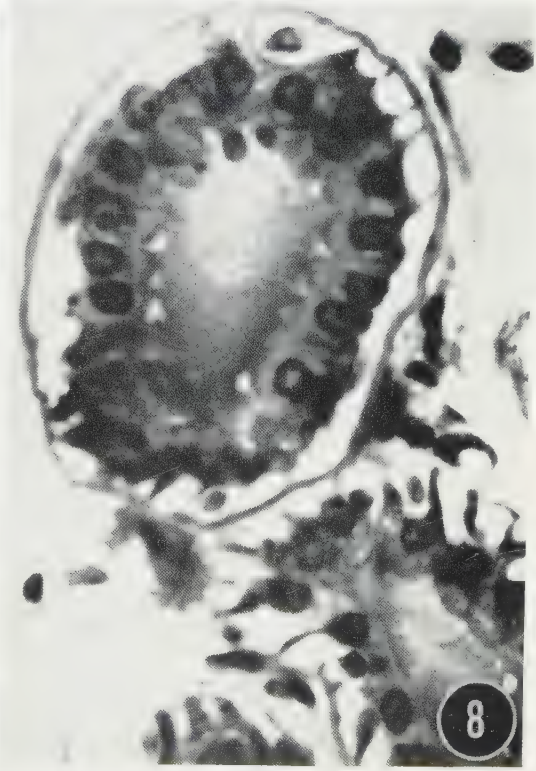

8

PLATE 3

EXPLANATION OF FIGURES

9 Alkaline phosphatase activity in the myoepithelial cells and in the basal cytoplasm of the apocrine glands from the perianal region. Approx. × 50.

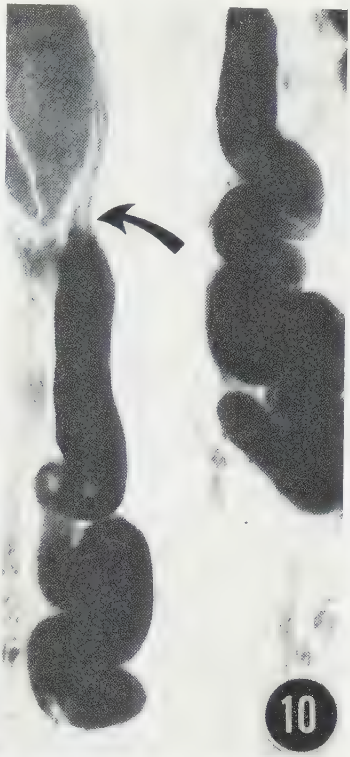
10 Apocrine glands from the vulva showing large concentrations of alpha naphthol esterase activity in the secretory portion and a weak reaction in the duct. The curved arrow shows the transition between the secretory portion below and in the duct above. Approx. × 50.

11 Numerous nerve fibers containing acetylcholinesterase around an apocrine sweat gland in the vulva. Approx. × 50.

12 Eccrine sweat glands in the palm, with large amounts of glycogen in the clear cells, and a moderate amount of nonglycogen, PAS-positive granules in the dark cells. The myoepithelial cells are very large. Approx. × 200.

13 Alkaline phosphatase reactive eccrine sweat glands in the palm. The reactivity is localized in the cuticular border. Approx. × 50.

9



10

11

12

13

he Blood Groups of Chimpanzees: The h-Hr (CDE/cde) Blood Types[1]

ALEXANDER S. WIENER AND EVE B. GORDON
From the Serological Laboratory of the Office of the Chief Medical Examiner of New York City, and the Division of Immunohematology of the Jewish Hospital of Brooklyn, New York

The first study of the Rh-Hr types in impanzees was reported by Wiener and ade ('45). At the time of that study, ly antisera of specificities anti-**Rh**$_0$ (anti-), anti-**rh**′ (anti-C), anti-**rh**″ (anti-E) d anti-**hr**′ (anti-c) were available.[2] ood specimens from 10 chimpanzees ere tested, and it was found that all gave e identical reactions with these 4 re- ents. In the tests by the saline agglutina- n method, with the anti-**Rh**$_0$, anti-**rh**′, d anti-**rh**″ sera, the reactions were either gative or very weak, and the weak clump- g that did occur could have been due to teroagglutinins. The anti-**hr**′ serum ailable at the time had a very high titer 50 units) in saline media, and it was und that the chimpanzee blood speci- ens all reacted to the same titer with is reagent as human type rh (type ddee) cells. It was therefore concluded at the chimpanzees all belonged to an -Hr blood type corresponding to human od type rh.

In 1952 and 1953, the Rh-Hr types chimpanzees were reinvestigated by iener ('52) and by Wiener, Gavan and rdon ('53). During the interval of 8 ars since the previous study, new thods of testing with Rh-Hr and other tibodies had been devised, namely, the nglutination method, the anti-globulin hnic and the proteolytic enzyme method Viener, '54). With the aid of these newer hnics, and the more potent reagents ailable, it was then found that blood ls of chimpanzees reacted with anti- $_0$ sera as well as anti-**hr**′ serum, and to proximately the same titer as human red ls having these blood factors. A total 8 chimpanzees were tested, and the od cells of all 8 gave the same reactions with these reagents. These results proved that chimpanzees are actually **Rh**$_0$ positive, and not **Rh**$_0$ negative as originally believed.

Since 1953, Rh-Hr antisera of additional specificities have become available. Therefore, when Dr. Maitland Baldwin, Chief of the Surgical Neurology Branch of the National Institute of Neurological Diseases and Blindness, made available to us blood samples from 14 chimpanzees being studied at that institute, the opportunity was used to carry out further investigations on their Rh-Hr blood types.

MATERIALS AND METHODS

The blood specimens were received by mail and arrived in excellent condition. The sera were separated from the clots, and blood suspensions prepared as described in the previous paper (Wiener and Gordon, '60). In addition to the saline suspensions of the untreated red blood cells, saline suspensions of ficinated red blood cells were prepared as follows. Chimpanzee red blood cells were washed in normal saline solution three times, and 10 drops of the packed washed red cells were mixed with one drop of a one per cent saline solution of ficin. The mixture was incubated at 37°C for one hour, and the ficinated cells were then washed once with saline solution to stop the action of the enzyme. The washed ficinated cells were then suspended in enough saline solution to make a 2 per cent suspension. Similar suspensions of untreated and ficinated cells were prepared of human blood cells of known types rh, Rh_1Rh_1 (CCDee), $Rh_1^w rh$ (C^wCDee), Rh_2Rh_2 (ccDEE), Rh_2rh (ccDEe), Rh_o^v (ccddeeV), etc., for use as controls with the appropriate antisera.

---

[1] In this paper, in conformity with the recommendation of the Committee on Medicolegal Problems of the American Medical Association (Wiener, Owen, Stormont and Wexler, '57), symbols for agglutinogens, phenotypes, and blood group systems are printed in regular type, symbols for blood factors and their corresponding antibodies in **boldface** type, and symbols for genes and genotypes in *italics*.

[2] The C-D-E symbols used in this paper were inserted by the author at the request of the editor.

For testing for blood factor **Rh**$_o$ by the saline agglutination method, an exceptionally potent (titer 2,000 units) anti-**Rh**$_o$ serum (No. 2, in table 1) was available. This was diluted 40 times for use, so as to have a titer of 40 to 50 units for human Rh-positive red cells. The diluted reagent was prepared in two different ways: (a) by adding 39 volumes of saline solution, and (b) by adding 39 volumes of a mixture of saline solution with one tenth its volume of 30 per cent bovine albumin. These two diluted reagents were used for testing saline suspensions of unmodified chimpanzee red cells, both directly and by the titration method in parallel with human red cells of known Rh-Hr types. Two different anti-**Rh**$_o$ sera (No. 3 and No. 4 of table 1) containing "univalent" **Rh**$_o$ antibodies were used in the study. One (serum No. 3), which had a titer of approximately 150 units for ficinated human Rh-positive cells, was used by the titration method for testing ficinated chimpanzee red cells. The second reagent (serum No. 4) was also used by the ficinated cell method, but only undiluted, and the intensity of the reactions recorded. In addition, an anti-rhesus guinea-pig serum (serum No. 1) was used, which was kindly made available to us by Dr. R. E. Rosenfield. This serum was diluted with an equal volume of saline solution, and then absorbed three times with a half volume of pooled, packed, washed human red cells of types A_1rh and Brh. The absorbed guinea-pig serum was then used by titration method against saline suspensions of untreated chimpanzee red cells, in parallel with human red cells of known Rh-Hr blood types.

For testing for blood factor **rh′**, an anti-**Rh**$_o$′ (Anti-C+D) serum (serum No. 5), to which anti-**Rh**$_o$ blocker had been added, was used. This reagent, which had a titer of approximately 30 units for human red cells having the factor **rh′**, was used undiluted by the saline agglutination method and the direct reactions recorded. In addition, a "pure" anti-**rh′** serum (serum No. 6 was used, which had a titer of approximately 200 units for human red cells having the factor **rh′**. This reagent, which wa kindly provided to us by Dr. P. Levine, wa used by the titration method against ficinated chimpanzee red cells. For testing fo blood factor **rh″**, two different reagent were also used, one a "blocked" anti-**Rh**$_o$ (anti-D+E) serum (serum No. 7) by th saline agglutination method, and the second (serum No. 8) a pure anti-**rh″** seru with a titer of approximately 100 units fo ficinated human red cells having the bloo factor **rh″**. For testing for blood facto **rh**^{w_1} (C^w), an antiserum (serum No. 9) o specificity $rh^{w_1} + K$ ($C^w + K$), was available. This had a titer of approximately 2 to 30 units for ficinated human red cell having the **rh**^{w_1} factor, and it was used undiluted for testing the ficinated red cells

Three different antisera were used fo testing for blood factor **hr′**, by the ficinate cells method. One of the reagents (No. 10 in table 2) was used undiluted, and only the direct reactions recorded, while the other two (Nos. 11 and 12), having titers of approximately 40 and 20 units, respectively, were used by the titration method An exceptionally potent anti-**hr″** serum (serum No. 13), with a titer of approximately 150 to 200 units of ficinated human re cells having the blood factor **hr″** was used which had been obtained from the Biotes Laboratories. For the sake of economy this serum was first diluted with 4 volume of saline solution, and the diluted reagen was then titrated against ficinated chimpanzee red blood cells. In addition, a polyvalent serum (serum No. 14) of specificit **rh″** + **hr′**, with a titer of 30 to 50 unit for ficinated human cells having these tw factors was used by the titration metho for testing the ficinated chimpanzee re cells. A very interesting serum (serum No 15), kindly provided by Dr. Maurice Shapiro, was also used, but only for testing th blood from the two group O chimpanzees because the serum came from a group patient and had not been absorbed to remove its alpha and beta isoagglutinins This patient (Shabalala) belongs to typ

TABLE 1

Results of tests with Rh antisera on blood specimens of 14 chimpanzees

Blood of	Anti-rhesus guinea-pig Serum No. 1 Saline (Titer)	Anti-**Rh**$_o$ (Anti-D)				Anti-**rh**′ (Anti-C)		Anti-**rh**″ (Anti-E)		Anti-**Rh**$^w_1$ (Anti-C^w)	Rh type of chimpanzee
		Serum No. 2 Saline (Titer)		Serum No. 3 Ficin (Titer)	Serum No. 4 Ficin (Direct)	Serum No. 5 Blocked anti-**Rh**$_o$′ Saline (Direct)	Serum No. 6 Ficin (Titer)	Serum No. 7 Blocked anti-**Rh**$_o$″ Saline (Direct)	Serum No. 8 Ficin (Titer)	Serum No. 9 Anti-globulin (Direct)	
		a	*b*								
Chimpanzee											
1. Iris	3	44	24	180	+++	tr.	0	—	0	—	Rh_o^{Ch}
2. Evelyn	2	24	28	190	+++	tr.	0	—	0	—	Rh_o^{Ch}
3. Sampson	3	44	32	220	+++	—	0	—	0	—	Rh_o^{Ch}
4. Jerry	2	32	32	180	+++	—	0	—	0	—	Rh_o^{Ch}
5. Cindy	3	24	28	180	+++	—	0	—	0	—	Rh_o^{Ch}
6. Queenie	3	40	48	250	+++	—	0	—	0	—	Rh_o^{Ch}
7. Bike	1	24	24	190	+++	tr.	0	—	0	—	Rh_o^{Ch}
8. Patch	2	24	24	180	+++	tr.	0	—	0	—	Rh_o^{Ch}
9. Tiny	5	16	20	250	+++	tr.	0	±	0	—	Rh_o^{Ch}
10. Lady	2	24	20	180	+++	—	0	—	0	—	Rh_o^{Ch}
11. Georgie	2	16	24	220	+++	±	0	±	0	—	Rh_o^{Ch}
12. Baldie	2	24	48	220	+++	±	0	±	0	—	Rh_o^{Ch}
13. Dotty	2	20	30	220	+++	+	0	±	0	—	Rh_o^{Ch}
14. J. B.	2	14	12	180	+++	—	0	tr.	0	—	Rh_o^{Ch}
Controls (*human cells*)											
Type rh	2	0	0	0	—	—	0	—	0	—	
Type $Rh_1{}^wRh_1$	24	48	40	160	+++	+++	200	—	0	++±	
Type Rh_2rh	12	24	14		++±	—	0	++±	90	—	
Type Rh_zRh_o	16			140	++±	++±	190	++	100	—	

TABLE 2

Results of tests with Hr antisera on blood specimens of chimpanzees

Blood of	Anti-hr′ (Anti-c)			Anti-hr″ (Anti-E) Serum No. 13 Ficin (Titer)	Anti-hr′ + Anti-rh″ (Anti-c+E) Serum No. 14 Ficin (Titer)	Anti-Hr + Anti-hr^S (Anti-C+c+E+e+e^S) Serum No. 15 Ficin (Titer)	Rh-Hr Type of chimpanzee
	Serum No. 10 Ficin (Direct)	Serum No. 11 Ficin (Titer)	Serum No. 12 Ficin (Titer)				
Chimpanzee							
1. Iris	+ + ±	21	12	0	0	0	$\bar{\text{R}}\text{h}_o^{\text{Ch}}$ ($\text{D}^u\text{c}-{}^{\text{Ch}}$)
2. Evelyn	+ + +	18	4	½	0		$\bar{\text{R}}\text{h}_o^{\text{Ch}}$
3. Sampson	+ + ±	18	11	½	0		$\bar{\text{R}}\text{h}_o^{\text{Ch}}$
4. Jerry	+ + ±	36	20	0	0		$\bar{\text{R}}\text{h}_o^{\text{Ch}}$
5. Cindy	+ + ±	9	6	0	0		$\bar{\text{R}}\text{h}_o^{\text{Ch}}$
6. Queenie	+ + ±	33	10	0	0		$\bar{\text{R}}\text{h}_o^{\text{Ch}}$
7. Bike	+ + ±	21	11	0	0		$\bar{\text{R}}\text{h}_o^{\text{Ch}}$
8. Patch	+ + ±	18	6	0	0		$\bar{\text{R}}\text{h}_o^{\text{Ch}}$
9. Tiny	+ + ±	72	12	0	0		$\bar{\text{R}}\text{h}_o^{\text{Ch}}$
10. Lady	+ + ±	33	14	0	0		$\bar{\text{R}}\text{h}_o^{\text{Ch}}$
11. Georgie	+ + +	15	12	0	0		$\bar{\text{R}}\text{h}_o^{\text{Ch}}$
12. Baldie	+ + +	30	12	0	0		$\bar{\text{R}}\text{h}_o^{\text{Ch}}$
13. Dotty	+ + ±	36	11	0	0		$\bar{\text{R}}\text{h}_o^{\text{Ch}}$
14. J. B.	+ + ±	24	9	0	0	0	$\bar{\text{R}}\text{h}_o^{\text{Ch}}$
Controls (*human cells*)							
Type rh	+ + +	40	16	26	48	12	
Type Rh_1Rh_1	−	0	0	24	0	24	
Type Rh_2Rh_2							
Type Rh_1rh	+ + ±	36	12	0		28	
Type Rh_2rh	+ + ±	30	16	12	24	30	
Type Rh_zRh_o							

$_o^{abcd}$ (no C-D-E equivalent), and her um reacts with all human red cells ex- pt those of type $\overline{\overline{R}}$h$_o$ (D——/D——) d $\overline{\overline{R}}$h^w (DC^w—/DC^w—).[3] By absorption periments, Shapiro ('60) has been able fractionate from Shabalala serum re- ents of specificities anti-**Hr** (anti-C+c+ -e) and anti-**hr**^{s} (anti-e^s), respectively. erefore, for the purpose of the present udy this serum (serum No. 15) has been signated simply as anti-**Hr** + **hr**^{s}.

For testing for the factors **Rh**^{A} (D^A), **Rh**^{B} ^{B}), **Rh**^{C} (D^C) and **Rh**^{D} (D^D), the antisera erums Nos. 16, 17, 18, and 20, table 3) om the original 4 cases were available Viener, Geiger and Gordon, '57; Unger, ener and Weiner, '59; Unger and ener, '59; Unger, Wiener and Katz, '59; cks, Wiener, Jahn, Spurling and Unger, 9; Wiener and Wexler, '59). In addition, second serum (No. 19), apparently of ecificity anti-**Rh**^{C} was used, which had en obtained from a different case Viener and Unger, '60). Two additional tisera (serums Nos. 21 and 22), con- ning antibodies of related specificities d tentatively designated anti-**Rh**^{Br} (D^{Br}) d anti-**Rh**^{Lo} (D^{Lo}), respectively, were also ailable. All these reagents were used by e titration method against ficinated chim- nzee red cells, in parallel with human $_o$-positive and **Rh**$_o$-negative cells.

In addition to these tests, others were rried out with reagents of specificities ti-**hr** (f or ce), anti-**hr**^{V} (V) anti-**P**, anti- anti-**F** and others. The reactions ob- ned with these additional reagents were most cases not clear cut and they will t be presented in this paper.

RESULTS

For the sake of clarity, the results have en subdivided into three parts, namely, e reactions with Rh antisera (table 1), e reactions with Hr antisera (table 2), d the reactions with antisera specific for od factors associated with **Rh**$_o$ (table 3).

Rh factors. The blood specimens of all chimpanzees gave similar reactions th the various Rh antisera. The reac- ns with anti-**Rh**$_o$ sera nos. 2, 3, and 4 re indistinguishable from those of hu- n **Rh**$_o$-positive red cells, indicating that e blood cells of all chimpanzees have an **Rh**$_o$ factor, confirming the previous report of Wiener, Gavan and Gordon. However, in tests with anti-rhesus serum (serum 1, table 1) the reactions of chimpanzee red cells resemble those of human **Rh**$_o$-negative cells. These results indicate that while chimpanzee red cells have an **Rh**$_o$ factor, the factor is not identical with the **Rh**$_o$ factor of human blood. The failure of chimpanzee blood to react with anti-rhesus guinea-pig serum indicates that chimpanzee cells do not react with *all* reagents which appear to be of specificity anti-**Rh**$_o$. This may explain why in the original study of Wiener and Wade, with the reagents available in 1943, the chimpanzee blood samples reacted as though they were **Rh**$_o$ negative.

The results of the tests with sera nos. 5, 6, 7 and 8 indicate that chimpanzee blood cells lack both the blood factors **rh′** and **rh″**. The weak and irregular reactions sometimes obtained with sera 5 and 7 may be attributed to incomplete blocking of the **Rh**$_o$ antibodies in these two reagents and/or to heteroagglutinins. The results of the tests with serum no. 9 indicate that chimpanzee red blood cells also lack blood factor **rh**^{w_1}.

In summary, the reactions with antisera of specificities anti-**Rh**$_o$, anti-**rh′**, anti-**rh″**, and anti-**rh**^{w} indicate that chimpanzee red cells have an agglutinogen resembling that of human blood of type Rh$_o$ (ccDee). However, that the agglutinogen of chimpanzee blood is different from the human agglutinogen Rh$_o$ is shown by the negative reactions of the former with anti-rhesus guinea-pig serum. Therefore the Rh type of chimpanzee red cells may be designated by a symbol such as Rh$_o^{ch}$ (ccD^{u}ee^{ch}), in order to indicate its similarity to the human type Rh$_o$ and at the same time to emphasize the differences.

---

[3] As explained in the Special Report of the Committee on Medicolegal Problems (Wiener, Unger and Sacks, '60) of the American Medical Association, the symbols having a capital R with a double bar above it ($\overline{\overline{R}}$) refer to blood lacking all the factors of the two pairs rh′–hr′ (C–c) and rh″–hr″ (E–e), while a single bar ($\overline{R}$) refers to blood lacking both factors of the pair rh″–hr″ (E–e) but having at least one factor of the pair rh′–hr′ (C–c).

TABLE 3

Results of tests for blood factors $\mathbf{Rh^A}$, $\mathbf{Rh^B}$, $\mathbf{Rh^C}$, $\mathbf{Rh^D}$, *etc. on blood specimens from chimpanzees*

Blood of	Anti-$\mathbf{Rh^A}$ (Anti-D^A) Serum No. 16 Ficin (Titer)	Anti-$\mathbf{Rh^B}$) (Anti-D^B Serum No. 17 Ficin (Titer)	Anti-$\mathbf{Rh^C}$ (Anti-D^C)		Anti-$\mathbf{Rh^D}$ (Anti-D^D) Serum No. 20 Ficin (Titer)	Anti-$\mathbf{Rh^{Br}}$ (Anti-D^{Br}) Serum No. 21 Ficin (Titer)	Anti-$\mathbf{Rh^{Lo}}$ (Anti-D^{Lo}) Serum No. 22 Ficin (Titer)	Rh-Hr type of chimpanzee
			Serum No. 18 Ficin (Titer)	Serum No. 19 Ficin (Titer)				
Chimpanzee								
1. Iris	11	1½	5	12	1½	4	6	$\overline{\mathrm{Rh}}_{\mathrm{o}}^{\mathrm{Ch}}$
2. Evelyn	6	2	5	10	2	6	3	$\overline{\mathrm{Rh}}_{\mathrm{o}}^{\mathrm{Ch}}$
3. Sampson	7	1½	4	13	1½	8	6	$\overline{\mathrm{Rh}}_{\mathrm{o}}^{\mathrm{Ch}}$
4. Jerry	10	1½	3	12	1½	6	7	$\overline{\mathrm{Rh}}_{\mathrm{o}}^{\mathrm{Ch}}$
5. Cindy	7	1½	6	24	1½	6	6	$\overline{\mathrm{Rh}}_{\mathrm{o}}^{\mathrm{Ch}}$
6. Queenie	11	2	6	16	2	5	11	$\overline{\mathrm{Rh}}_{\mathrm{o}}^{\mathrm{Ch}}$
7. Bike	20	2	6	12	1½	2	12	$\overline{\mathrm{Rh}}_{\mathrm{o}}^{\mathrm{Ch}}$
8. Patch	12	1½	4	22	2	6	4	$\overline{\mathrm{Rh}}_{\mathrm{o}}^{\mathrm{Ch}}$
9. Tiny	16	1½	6	40	2	6	7	$\overline{\mathrm{Rh}}_{\mathrm{o}}^{\mathrm{Ch}}$
10. Lady	12	3	6	24	3	5	11	$\overline{\mathrm{Rh}}_{\mathrm{o}}^{\mathrm{Ch}}$
11. Georgie	14	1½	6	24	2½	6	8	$\overline{\mathrm{Rh}}_{\mathrm{o}}^{\mathrm{Ch}}$
12. Baldie	12	2	6	16	2½	6	11	$\overline{\mathrm{Rh}}_{\mathrm{o}}^{\mathrm{Ch}}$
13. Dotty	11	1½	6	12	1½	6	11	$\overline{\mathrm{Rh}}_{\mathrm{o}}^{\mathrm{Ch}}$
14. J. B.	12	1½	6	24	2	2	4	$\overline{\mathrm{Rh}}_{\mathrm{o}}^{\mathrm{Ch}}$
Controls (*human cells*)								
$\mathbf{Rh_o}$ positive	48	24	5½	18	16	12	22	
$\mathbf{Rh_o}$ negative	0	0	0	0	0	0	0	

Hr factors. The results of the tests
th antisera containing Hr antibodies are
mmarized in table 2. The reactions with
ra no. 10, no. 11 and no. 12 indicate that
impanzee red cells have a blood factor
ntical with or very similar to the human
od factor **hr′**, confirming the previous
ports of Wiener and Wade and of Wiener,
van and Gordon. On the other hand,
e results of tests with serum no. 13 indi-
te that chimpanzee red cells lack the
ctor **hr″**. Thus, for chimpanzee blood
e reciprocal relationship between factors
″ and **hr″** does not appear to hold, since
th members of this contrasting pair of
od factors are absent from chimpanzee
l blood cells. This can be indicated by
ding to the symbol for the chimpanzee
blood type a single bar above the capital
as follows: $\bar{R}h_o^{Ch}$ $(D^uc-)^{Ch}$. These find-
gs and conclusions are supported by the
ults of tests with the polyvalent sera
. 14 (anti-**hr′** + **rh″**) and no. 15 (anti-
+ **hr**^{s}) (anti-C+c+E+e+e^s) both of
ich failed to clump chimpanzee red
ls, again demonstrating the absence
m such cells of the blood factors **rh′**,
″, **hr″**, **hr**^{s} and **Hr**.

Blood factors Rh^A, Rh^B, Rh^C and Rh^D.
e blood specimens of the 14 chimpan-
s were also tested for the blood factors
ociated with **Rh**$_o$, using antisera of spe-
cities anti-**Rh**^{A}, anti-**Rh**^{B}, anti-Rh^C, and
ti- **Rh**^{D} as well as two additional antisera
nporarily designated as anti-**Rh**^{Br} and
ti-**Rh**^{Lo}, respectively. Results of these
ts are shown in table 3. Except for tests
h anti **Rh**^{C} serum, the reactions of chim-
nzee red cells with these reagents were
lower titer than those of human **Rh**$_o$-
itive red cells. These findings indicate
t chimpanzee red cells have blood fac-
Rh^C as fully developed as in Rh-positive
man blood, while blood factors **Rh**^{B} and
^{D}, if present at all, are low grade vari-
ts. The reactions of chimpanzee cells
h anti-**Rh**^{A} serum are of intermediate
ensity, the titer of this reagent for chim-
nzee red cells being about one fourth as
h as for human Rh$_o$-positive red cells.
e blood factors **Rh**^{Br} and **Rh**^{Lo} which are
the process of being investigated, appear
be present in chimpanzee red cells, but
titers of these antisera are about one third to one half as high for chimpanzee red cells as for human **Rh**$_o$-positive red cells.

DISCUSSION

The results of the experiments described in the present paper, as well as in previous reports, indicate that all chimpanzees are **Rh**$_o$ positive, and belong to the identical Rh-Hr type, to which has been assigned the symbol $\bar{R}h_o^{Ch}$. This particular symbol was selected to indicate similarity between chimpanzee red cells and human red cells of type Rh$_o$ in their reactions with Rh-Hr antisera. Since chimpanzee red cells fail to react with anti-**hr″** serum as well as anti-**rh″** serum, a single bar has been placed above the capital R, as in the symbol for the analogous Rh-Hr type found in certain rare human bloods. Other peculiarities of chimpanzee red cells are that while blood factor **Rh**^{C} appears to be fully developed, the other blood factors that occur in association with blood factor **Rh**$_o$ in human Rh-positive red cells, though apparently present also in chimpanzee red cells, appear to be variants. Rather than attempt to indicate all these facts in the symbol for Rh-Hr type in chimpanzee red cells a superscript Ch has been added to the symbol. The advantage of a symbol such as $\bar{R}h_o^{Ch}$ is self evident, because this symbol epitomizes the most important serological properties of chimpanzee red cells. However, no attempt is made to include *all* the facts known regarding the reactions of chimpanzee red cells in the symbol, because this would entail change in the symbol as new facts are learned. Thus, the symbol serves as a mnemonic, and this need not be changed whenever further studies add new facts regarding the reactions of chimpanzee red cells with Rh-Hr antisera. In fact, even if future studies fail to confirm some of the observations reported in this paper, it would not be necessary to change the symbol which has been adopted by us for chimpanzee Rh-Hr type.

A number of other observations provide further evidence of the similarities between the Rh-Hr agglutinogens of human and chimpanzee blood. Firstly, the titers of almost all anti-**Rh**$_o$ sera are approximately the same for chimpanzee red cells as for human Rh-positive cells. Secondly, as shown by Wiener and Gordon ('53), if chimpanzee red cells are maximally coated with **Rh**$_0$ antibodies, they will react with anti-globulin serum to the same titer as maximally coated human Rh-positive cells. This indicates that chimpanzee red cells have approximately the same number of sites for Rh-Hr agglutinogens on their surface as human red cells. Similar results were obtained in tests with sera from patients with hemolytic anemia, containing autoantibodies. This supports Wiener's suggestion (Wiener, Gordon and Gallop, '53) that such warm autoantibodies react with the nucleus of the Rh-Hr agglutinogens, not only in human red cells, but also in chimpanzee red cells.

If tests on larger numbers of chimpanzees confirm our observations made up to the present time that all chimpanzees are **Rh**$_0$ positive and of the identical Rh-Hr type, this would preclude the occurrence of isosensitization to any of the Rh-Hr factors among chimpanzees. On the other hand, this does not preclude the possibility that at one time Rh-negative chimpanzees existed, but were eliminated from the population, perhaps by the selective action of isoimmunization by pregnancy. At any rate, Rh-Hr hemolytic disease does not appear to be a problem with which chimpanzees have to contend with at the present time.

SUMMARY

In tests on blood specimens from 14 chimpanzees with a battery of Rh-Hr antisera identical results were obtained with all 14 specimens. Chimpanzee red cells react with antisera of specificities anti-**Rh**$_0$ (anti-D) and anti-**hr′** (anti-c), to approximately the same titer as human red cells having these two blood factors. On the other hand, blood factors **rh′** (C) **rh″** (E), **hr″** (e), **hr**$^{\text{s}}$ (e$^{\text{s}}$) and **Hr** (C+c+E+e) appear to be absent from chimpanzee red cells. Blood factor **Rh**$^{\text{C}}$ (D$^{\text{C}}$) is apparently fully expressed in chimpanzee red cells while the related factors **Rh**$^{\text{A}}$ (D$^{\text{A}}$), **Rh**$^{\text{B}}$ (D$^{\text{B}}$) and **Rh**$^{\text{D}}$ (D$^{\text{D}}$), etc., appear to be variants. Another peculiarity of chimpanzee red cells is that they fail to react or react only weakly with anti-rhesus guinea-pig serum which reacts strongly with human Rh-positive cells. To indicate all the
facts concerning the Rh-Hr factors
chimpanzee red cells, the symbol $\overline{\text{Rh}}$
(D$^{\text{u}}$c—$^{\text{Ch}}$) has been selected for the chi
panzee Rh-Hr blood type.

ADDENDUM

Among the articles published by th
authors, the present article is unique, sinc
it is the only one which expresses th
findings in terms of the C-D-E symbols i
addition to Wiener's original Rh-Hr term
nology. As explained in the footnote
the beginning of the article, this was do
at the edtior's request, even though th
multiplicity (as many as 20 or more) o
C-D-E equivalents for a single unambi
uous Rh-Hr symbol in some cases, and th
absence of equivalents in other case
made it difficult to comply. The inclusio
of the C-D-E symbols may perhaps conve
the false impression to certain reade
that the authors' position has changed r
garding this question. This is not so, an
this addendum has been prepared in orde
to anticipate and correct any such misa
prehension.

The authors maintain unequivocall
that for reasons presented in detail els
where (Wiener, Owen, Stormont and We
ler, '57; Wiener and Wexler, '58; Wiene
'60), and in order not to interfere wit
future scientific progress in this field, th
C-D-E notations must be discarded com
pletely and without delay. One reason wh
the authors agreed to the editor's reque
to include the C-D-E symbols was to gi
critical readers the opportunity to compa
the two nomenclatures, and to see f
themselves the contrast between scientif
precision of the original Rh-Hr nome
clature and the fallacies of the C-D-E not
tions. One must always bear in mind tha
the purpose of scientific symbols is to pr
sent facts tersely, but *without distortio*
or *misrepresentation.* That is why th
Rh-Hr and C-D-E symbols can never b
fully equivalent; the latter misrepresen
the facts. For example, as many as 1
different Rh-Hr factors have been foun
to date, but the C-D-E symbols recogniz
only 6, C-c, D-d, and E-e. A more detaile
statement concerning this problem, fro
the point of view of the anthropologis

ll be published in a later issue of this rnal.

ACKNOWLEDGMENTS

These studies were carried out with the chnical assistance of Mrs. Doris McSee, iss Louella Hinds, and Miss Patricia an.

This investigation was made possible ly through the kind collaboration of Drs. arles S. Bucknam and Dr. Maitland ldwin of the Branch of Neurosurgery of e National Institute of Neurological Dis- ses and Blindness in Bethesda, Md., who ovided the blood specimens from their lony of chimpanzees, which were used this study.

LITERATURE CITED

cks, M. S., A. S. Wiener, E. F. Jahn, C. L. Spurling and L. J. Unger 1959 Isosensitization to a new blood factor Rh^D, with special reference to its clinical importance. Ann. Int. Med., *51:* 740–747.

apiro, M. 1960 Serology and genetics of a new blood factor hr^S. J. For. Med., *7:* 96–105.

ger, L. J., and A. S. Wiener 1959 A new antibody, anti-Rh^C resulting from isosensitization by pregnancy with special reference to the heredity of a new Rh-Hr agglutinogen, ℜh$_2^C$. J. Lab. and Clin. Med., *54:* 835–844.

ger, L. J., A. S. Wiener and L. Katz 1959 Studies on the blood factors Rh^A, Rh^B and Rh^C. J. Exp. Med., *110:* 495–510.

ger, L. J., A. S. Wiener and L. Weiner 1959 A new antibody (anti-Rh^B) in an Rh-positive patient resulting from blood transfusion. J. Amer. Med. Assoc., *170:* 1380–1383.

iener, A. S. 1952 Blood group factors in anthropoid apes and monkeys. I. Studies on a chimpanzee "Pan." Amer. J. Phys. Anthrop., n.s. *10:* 372–375.

——— 1954 Rh-Hr Blood Types. Applications in Clinical and Legal Medicine and Anthropology. 763 pp. Grune & Stratton, N. Y.

——— 1960 Modern blood group mythology. J. Forensic Med. (South Afr.), *7:* 166–176.

Wiener, A. S., J. A. Gavan and E. B. Gordon 1953 Blood group factor in anthropoid apes and monkeys. II. Further studies on the Rh-Hr factors. Amer. J. Phys. Anthrop., n.s. *11:* 39–45.

Wiener, A. S., J. Geiger and E. B. Gordon 1957 Mosaic nature of the Rh$_0$ factor of human blood. Exper. Med. Surg., *15:* 75–82.

Wiener, A. S., and E. B. Gordon 1953 Quantitative test for antibody globulin coating human red cells, and its practical applications. Amer. J. Clin. Path., *23:* 429–446.

——— 1960 The blood groups of chimpanzees. A-B-O groups and M-N types. Amer. J. Phys. Anthrop., n.s., *18:* 301–312.

Wiener, A. S., E. B. Gordon and C. Gallop 1953 Studies on autoantibodies in human sera. J. Immunol., *71:* 58–63.

Wiener, A. S., R. D. Owen, C. Stormont and I. B. Wexler 1957 Medicolegal applications of blood grouping test. A report of the Committee on Medicolegal Problems of the American Medical Association. J. Amer. Med. Assoc., *164:* 2036–2044.

Wiener, A. S., J. Jack and L. J. Unger 1960 Preuve de l'existence d'un nouveau gène allèle Rh, R^{1cd}. Rev. d'Hématol., in press.

Wiener, A. S., L. J. Unger and M. S. Sacks 1960 Special Report. Rh-Hr blood types; present status. Prepared by the Subcommittee on Medicolegal Blood Grouping Tests, for the Committee on Medicolegal Problems of the American Medical Association. J. Amer. Med. Assoc., *172:* 1158–1162 (March 12).

Wiener, A. S., and M. Wade 1945 The Rh and Hr factors in chimpanzees. Science, *102:* 177.

Wiener, A. S., and I. B. Wexler 1959 Heredity of the Blood Groups, 150 pp. Grune & Stratton, N. Y. C.

crements in Hand-Wrist Ossification

STANLEY M. GARN, CHRISTABEL G. ROHMANN AND
MEINHARD ROBINOW
Fels Research Institute, Yellow Springs, Ohio

Since the first longitudinal growth study
Gueneau de Montbeillard, the theoret-
l importance of increments has been at
st tacitly recognized (Scammon, '27, '30;
ompson, '44). Growth, after all, is not
e but rather change in size. For both
criptive and diagnostic purposes the
ividual size increment in a given time
y be more informative than height or
ight.

Over the years age-increment data
ged behind the obvious need. Except
Boas (1898) collectors of longitudinal
a ignored the problem of individual in-
ments. Only after the joint NEA-AMA
ort of 1933, did Shuttleworth turn to
remental analysis of Baldwin's 1914
ividual data (Anonymous, '33; Shuttle-
rth, '34). Further contributions were
de by Palmer and Reed ('35), Palmer,
wakami and Reed ('37), Simmons and
dd ('38) and Robinow ('42). Post-war
ditions to incremental data include those
Meredith and Meredith ('50), Thomp-
n ('51), Garn ('56) and Falkner ('58).

Despite the theoretical value of incre-
nts (cf. Tanner, '51, '52, '55), they have
ctical limitations, stemming from the
asuring error itself. Seasonal varia-
ns in the clothing worn may seriously
luce the accuracy of weight increments
Turner ('33) has shown. Moreover,
measuring error may be large in com-
rison to the normal variability of length
rements. Taking the measuring error
childhood as ±1 cm, the true semi-
nual stature increment as 3 cm, and
RMS variability of stature increments
approximately 1 cm (cf. Robinow, '42,
163) additive or subtractive errors can
sily exceed the limits of normal incre-
ntal variability in an individual case.

In contrast to height-weight increments,
erefore, increments in the number of
bony centers of the hand and wrist (as seen on radiographs) hold obvious advantages. Using serial radiographs, number counts (and therefore increments) can be substantially error-free. Particularly during the second and third years after birth, the number of new centers of ossification and the variability in the number of new centers are both large. It follows then, that such ossification increments may be particularly valuable as adjuncts to other measures of growth during the critical period of infancy and early childhood.

We have, therefore, investigated individual increments in the number of bony centers of the hand and wrist from the first through the 7th year in a pilot series of boys and girls. In addition to providing new sex-specific data on the variability of such increments during the pre-school years, individual departures from the generalized (median) incremental pattern have been considered. Moreover, the relationship between ossification increments and size increments has been analyzed for successive 6-month periods. Under test was the possibility that the magnitude of the ossification increment Δ_0, is indicative of the intensity of growth as confirmed by height increments (Δ_{ht}) and weight increments (Δ_{wt}) in the same time period.

METHODS AND MATERIALS

The present study is based upon individual 6-month increments in crown-heel length, body weight and the number of hand-wrist ossification centers of 154 clinically-healthy white Ohio-born boys and girls (Garn and Rohmann, '59). Except for additional sets of triplets and twins, specifically mentioned in the text, multiple births were excluded from the tabulations, as were like-sex siblings of index cases and children too young to have completed the full 28 hand-wrist ossification centers at the time the data-analysis was initiated.

Raw increments for length and weight were calculated (by subtraction) from individual values of recumbent length and weight corrected to nude weight. Sex-and-age specific cumulative frequency curves were then compiled from the raw distributions, converted into percentiles, and (having made preliminary tests for skewness) transformed into normalized T-scores using McCall's method (Johnson, '49) as validated by Lacey ('56) and described in Garn and Shamir ('58). Increments for the number of new ossification centers in each 6-month period were similarly derived from the number of centers observed in successive radiographs, converted into cumulative frequency curves and then into normalized T-scores. Individual normalized increment values were used in computing the correlations between ossification increments and size increments. The total of 44 sex- and age-specific increment correlations was expedited by the use of the IBM 602 Electronic Calculator.

Since the subject composition of the Fels Longitudinal Series is restricted in range from upper-lower to upper-middle class in the Warner classification, and is unusually homogeneous in respect to p rental ancestry, it is questionable whethe the increment percentiles will be appropr ate or normative to other populations di fering in nutritional status, or racial com position. However, in respect to *relation ships* between ossification increments an those for length and weight, generaliza tion may well be made since the relation ships involving Δ_o, Δ_{ht} and Δ_{wt} should b of the same order of magnitude except i malnourished or febrile populations.

FINDINGS

As a first step in the data analysis, cu mulative frequency distributions for suc cessive 6-month increments in the num ber of hand-wrist ossification centers wer set up for boys and girls respectively Examination of the 26 sex-specific distri butions covering the age-range 1.0 to 7. years showed the majority to be skewed often markedly so. Accordingly, as shown in table 1, percentiles rather than mean and standard deviations were employed as the appropriate measures of centra tendency and dispersion. Moreover, the sex differences were such that sex-specific rather than combined-sex increment per centiles were indicated.

Although at a few age intervals, notably 1.5–2.0 years in both sexes, the ossifica

TABLE 1

Percentiles for hand-wrist ossification increments 1.0 through 7.5 years

Age interval	Boys				Girls			
	Percentiles[1]			Skew	Percentiles[1]			Skew
	5	50	95		5	50	95	
years								
1.0–1.5	0	3	10[1]	2.3[2]	2	8	13[1]	0.8[2]
1.5–2.0	0	5	10	1.0	0	4	8	1.0
2.0–2.5	1	4	8	1.3	0	2	7	2.5
2.5–3.0	0	3	7	1.3	0	1	4	3.0
3.0–3.5	0	2	5	1.5	0	1	3	2.0
3.5–4.0	0	1	4	3.0	0	1	3	2.0
4.0–4.5	0	1	4	3.0	0	1	2	1.0
4.5–5.0	0	1	3	2.0	0	1	3	2.0
5.0–5.5	0	0	2	—	0	1	2	1.0
5.5–6.0	0	1	3	2.0	0	0	2	—
6.0–6.5	0	1	3	2.0	0	0	2	—
6.5–7.0	0	1	3	2.0	0	0	1	—
7.0–7.5	0	0	2	—	0	0	1	—

[1] Rounded to the nearest whole number of centers since a fraction of a center has no meaning.

[2] $\frac{P_{95} - P_{50}}{P_{50} - P_5}$.

n-increment distributions were symmet- al, skewness was generally consider- le throughout. The magnitude of the ewness is here best represented by the th to 95th percentile range divided by 5th to 50th percentile range. Against value of 1.0, for a fully symmetrical dis- bution, skewness values for actual ossi- ation increment distributions ranged up 3.0, as shown in columns 4 and 8 of le 1. The corresponding height and ight increments also proved skewed, though to a lesser degree, thus confirming skewness as a general property of growth increments in the age range considered.

Turning to the ossification increments, the wide variability during the first few years is immediately evident. For both sexes, except for girls in the age interval 1.0–1.5 years, a zero increment characterizes the 5th percentile, while in *individual* cases as many as 17 new centers of ossification may appear in a single 6-month period. Thus, while one normal

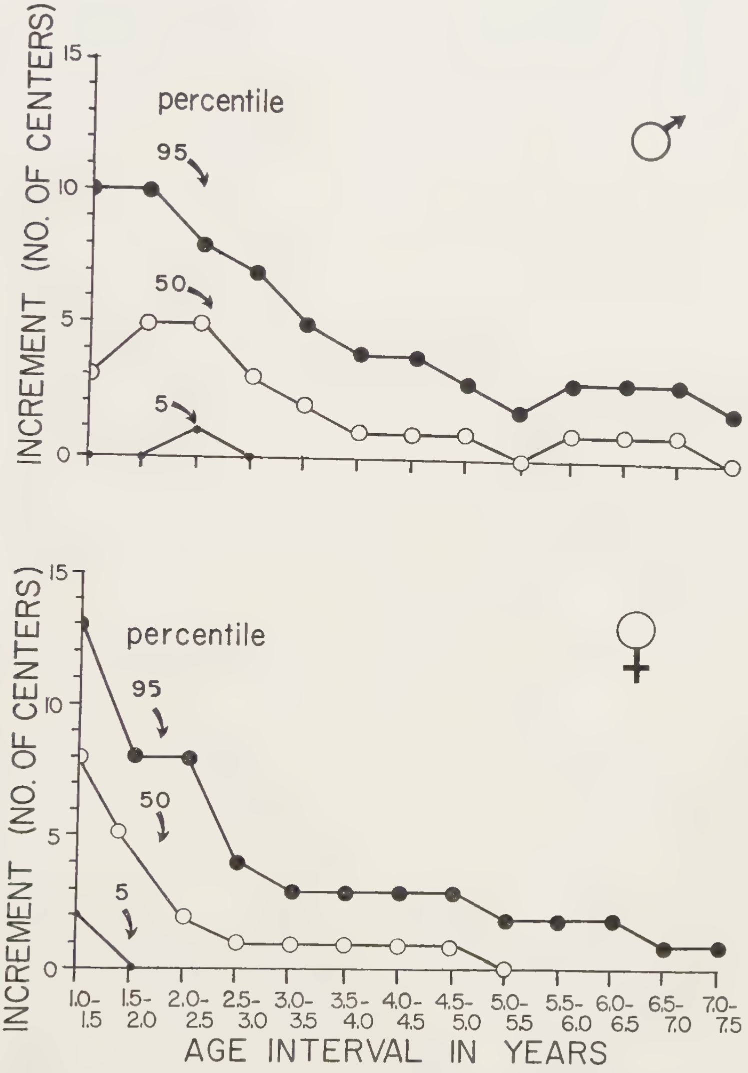


Fig. 1 Percentiles for 6-month hand-wrist ossification increments from 1.0–7.5 years. The increment distributions for both sexes are markedly skewed. Girls are advanced over boys by approximately 6 months.

child may exhibit no new centers of ossification in the hand and wrist, another may gain more than half of the full complement of 28 during the same age-interval. As shown in table 1, moreover, girls are consistently advanced over boys in the incremental pattern, by an amount approximating one 6-month class interval. However, marked variability of ossification increments is notable through the third year in both sexes.

Following the general custom of plotting the percentiles, as show in figure 1, both the skewness and the relative advancement of girls over boys is graphically apparent. This representation also serves to picture the incremental pattern of individual children against the percentil "norms." Some individual ossification increments as well as selected extrem cases, do more or less parallel the media increment pattern, as shown for Fels children 120 and 239 (fig. 2). However, mos children deviate from the median tren line in their ossification increment pattern. Some, as in cases 207 and 363, exhibit an unusually large number of new centers early, others may be delayed on year or more in the entire incrementa pattern (case 144), while still others ar characterized by irregular "bursts" of centers that make them quite unlike th smooth normative trend (case 85, fig. 3) Since individual incremental patterns o

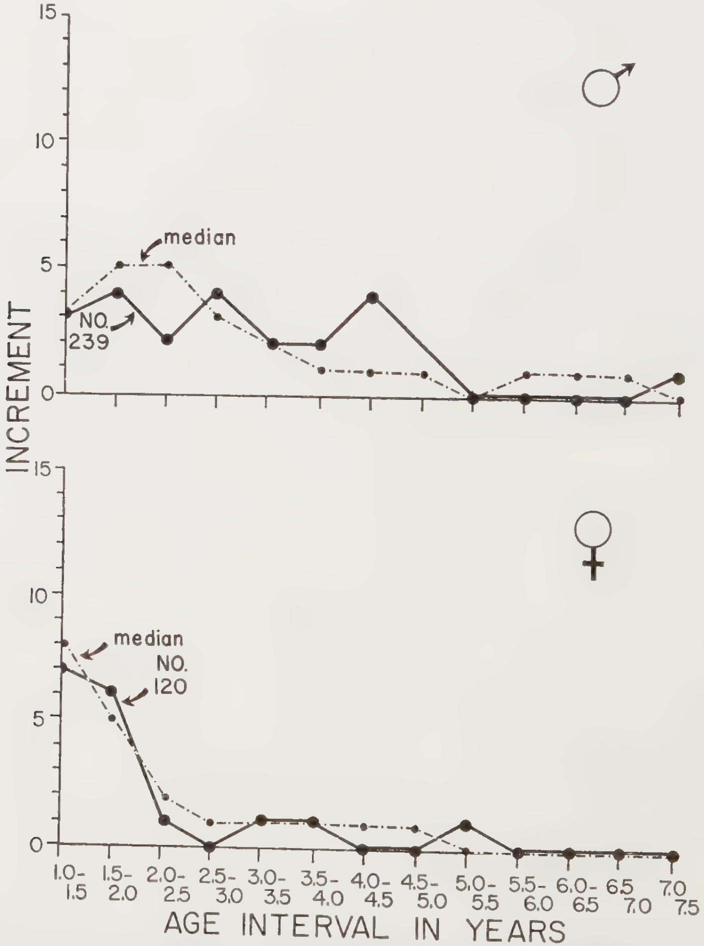


Fig. 2 Individual ossification increment patterns closely resembling the median trend lines. Only a minority of children fit the massed-data increment norms.

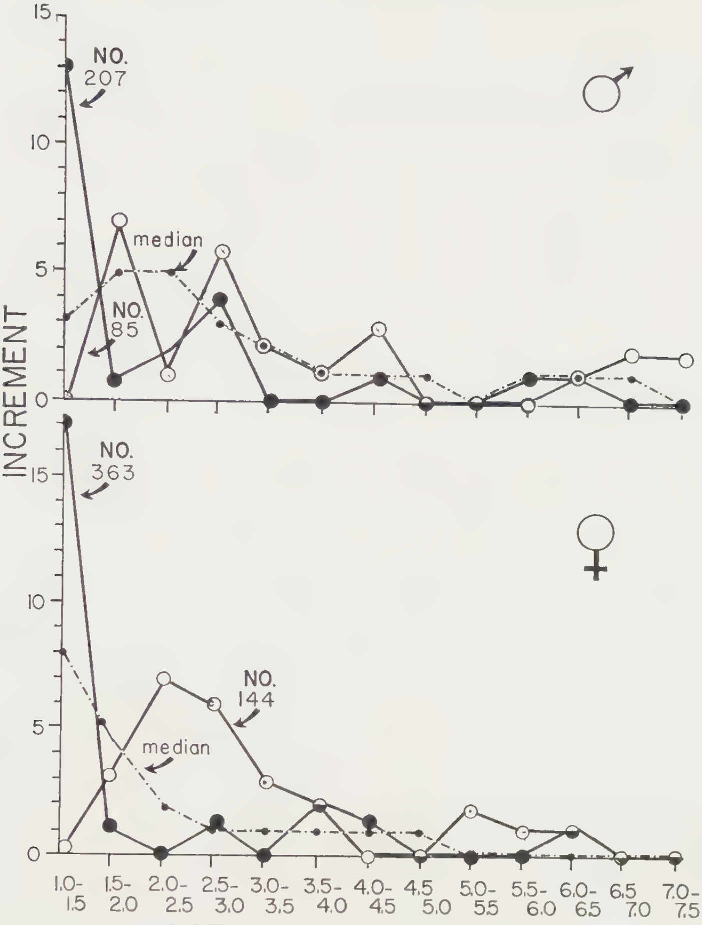


Fig. 3 Individual deviations from the increment norms showing marked precocity (cases 207 and 363), considerable retardation (case 144), and multiple "spurts" of ossification activity (case 85).

d-wrist ossification depart widely from
normative trend lines, the practical
ue of such increments for growth as-
sment is exceedingly doubtful.

Correlations involving individual incre-
nts in ossification, length and weight,
rd a further comparison. For ossifi-
ion, variability is considerable during
first few years. Height and weight
rements similarly exhibit a wide range.
us, with skewness appropriately cor-
ted by normalization, it is possible to
the hypothesis that the magnitude of
ossification increment is a measure of
rate of growth. However, while we
expected to discover that an above-average ossification increment during the first few years is indicative of particularly rapid growth, and that above-average increments in later years characterized later developing boys and girls, no such inference can be drawn from the correlations individually listed in table 2. For a total of 44 sex-specific correlations involving ossification increments and length or weight increments, there is no significant average departure from zero. Even through the third year, when variability in all three measures is still large, the correlations yield no certain indication that the magnitude of the ossification increment relates to the rate of linear growth or to

TABLE 2

Correlations between hand-wrist ossification increments and increments of length and weight from 1.0 to 6.5 years

Age interval	Length increment				Weight increment			
	Boys		Girls		Boys		Girls	
	N	r	N	r	N	r	N	
years								
1.0–1.5	73	−0.03[1]	67	0.14	74	−0.00	70	0.
1.5–2.0	67	−0.03	68	−0.00	78	−0.07	70	−0.
2.0–2.5	72	−0.12	68	0.18	74	−0.22	68	0.
2.5–3.0	77	−0.06	72	0.01	79	−0.13	71	−0.
3.0–3.5	76	0.10	72	−0.09	77	0.05	72	0.
3.5–4.0	74	0.23	71	0.08	76	0.21	71	−0.
4.0–4.5	74	−0.17	69	−0.02	74	0.00	69	−0.
4.5–5.0	75	0.16	68	0.19	76	−0.13	68	0.
5.0–5.5	73	−0.00	68	−0.01	74	0.01	69	0.
5.5–6.0	74	−0.11	65	0.24	74	0.12	66	0.
6.0–6.5	75	0.09	63	0.01	76	−0.01	63	−0.

[1] All correlations computed from normalized sex-specific T scores, thus minimizing the effects skewness in all three variables considered. For details see Garn and Shamir ('58) and t present text.

the magnitude of weight gain. A "burst" of centers, a common observation in clinical studies, is no indication of a surge of growth, while failure to add any new centers over a 6-month period cannot be used as an indication of (temporary) growth failure.

Since ossification increments have failed to meter growth as adjudged from crown-heel and weight increments, there was obvious interest in explaining differing individual incremental patterns of ossification. Previous evidence that the time of appearance of centers, the Z-score pattern of appearance, and the sequence of appearance were at least partly under genic control (Sontag and Lipford, '43; Reynolds, '43; Garn and Rohmann, '60) prompted us to compare the incremental pattern for monozygotic and dizygotic twins and triplet sets. The results, as plotted in figure 4, for a set of monozygotic twins and a like-sexed dizygote point to the close similarity of ossification increments in monozygotes and the greater divergence between dizygotic but still like-sexed products of a single pregnancy.

Inasmuch as the *magnitude* of hand-wrist ossification increments proved quite unrelated to length and weight increments, the value of such ossification increments as a measure of general growth activity may be considered doubtful in clinically healthy children. However, the similarity of incremental patterns in mo ozygotes as compared to dizygotic pai from the same pregnancy at least hin at genic determination.

DISCUSSION

It is evident from these findings that o sification increments during the pre-scho years are in a class by themselves. Th are skewed, considerably more skew than size increments. They are quite u related to length and weight increment There is evidence, drawn from twin a triplet comparisons, that the "increme tal pattern," that is the number of ne centers appearing in successive 6-mont periods, is largely under genic contr Only in the extent of sexual dimorphis with the girls approximately 6 mont ahead of the boys in the incremental pa tern, do the ossification increments coi cide with previous expectation.

At different ages the ossification incr ments are first negatively and then pos tively skewed and the skewness inde rises as high as 3.0 for some age interval Ossification increments, therefore, agre with the trend observed for height-weig increments by Shuttleworth ('34) bu exaggerate the natural skewness chara teristic of increment data. Clearly, mea and standard deviations are not appropr ate for increments, and the method o representation employed by the Meredith

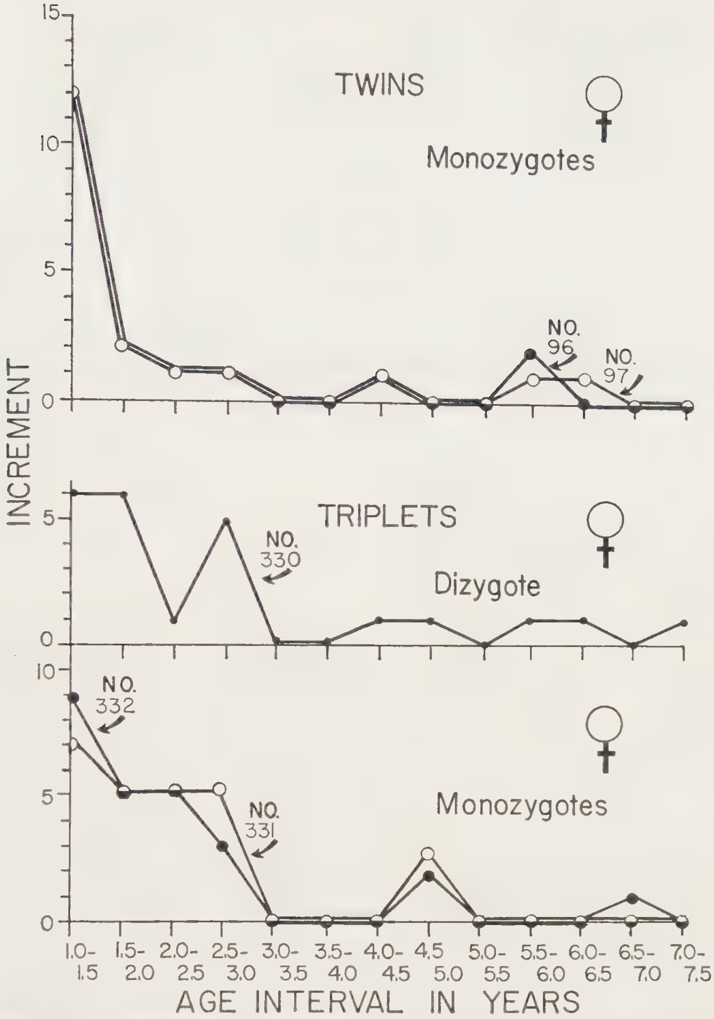


Fig. 4 Hand-wrist ossification increments in monozygotic and dizygotic pairings. In monozygotes, the increment patterns are nearly congruous with summed deviations (Σd) of 2 and 5 for pairings 96–97 and 331–332 respectively. The dizygotic pairings 330–331 and 330–332 are much more divergent with summed deviations of 14 and 15 respectively.

eredith and Meredith, ’50) is to be mmended. Particularly at the low end he increment distribution, representing cases of greatest clinical interest, ndard deviations are especially inept portraying the true variability of incre- nts.

he lack of correlation between ossifica- n increments (Δ_0) and size increments and Δ_{wt}) merits careful comment. For later ages, 4 and beyond, this may ply reflect the limited variability of ification increments, though one might expect the later-developing children to exhibit larger advances in both size and ossification. However, at earlier ages, ossification variability is considerable. One might expect that at 1.0–1.5, when some children evidence *no* new ossification centers and others exhibit as many as 13 to 17 new centers, size and ossification increments would be reasonably related. True, the relative imprecision of increments of length and weight may obscure a moderate correlation between size increments and ossification increments, but if this is so it raises additional doubts as to the practical utility of such increment data. The present results do not suggest that a "burst" of ossification centers marks a spurt in general growth, nor do they indicate that a total absence of new centers is diagnostic of growth failure in any 6-month period from the first through the 7th year.

The twin and triplet data herein assembled suggest that the "incremental pattern" is at least in part gene-determined. While there is little question that osseous maturation may be delayed in simple malnutrition, protein-deficiency growth failure and disorders limiting vitamin or nutrient absorption or utilization, the timing, patterning, sequence and increments of ossification appear in normal children to come under the class of genetic traits. For this reason the incremental pattern in various local and geographical races and in monozygotic and dizygotic twins is of particular interest. Comparative investigations now under way at Brazzaville and in Kampala, and twin studies in Louisville (cf. Falkner, '60) may be particularly contributory to elucidation of genetic determinants of ossification increments and patterning.

SUMMARY

1. Successive 6-month increments in length, weight and the number of postnatal hand-wrist ossification centers were individually determined for 154 Ohio-born boys and girls aged 1.0 to 7.5 years.

2. Increments for length and weight and especially ossification increments were markedly skewed, indicating the inapplicability of means and standard deviations to increments.

3. Relatively few children followed the median increment curve for ossification increments raising the question of the diagnostic value of such incremental data.

4. Correlations between ossification increments and those for length and weight approximated zero, even at ages characterized by marked variability in the number of new centers of ossification. Thus the number of new centers of ossification in a given 6-month interval was not an indication of the velocity of growth.

5. Comparison of the incremental pa terns of hand-wrist ossification in mo ozygotic and dizygotic twins and triple strongly suggested genic control.

ACKNOWLEDGMENTS

We are indebted to Laura L. Newe for preparation of illustrations, to Be jamin Apfelbaum for his assistance in th preparation of the bibliography, to D Frederic Silverman for his advice and Lois Conklin for her assistance in th preparation of the manuscript.

Financial support, in part, from r search grant A-3816 of the National Inst tutes of Health is herein acknowledged.

LITERATURE CITED

Anonymous 1933 Height-weight-age tables f children. J. Am. Med. Assn., *101:* 369–370.

Boas, F. 1898 Growth of Toronto children. R port of the U.S. Commissioner of Educatio 1896–7: 1541–1599.

Falkner, F. 1958 Some physical measuremen in the first three years of life. Arch. Dis. Child *33:* 1–9.

Falkner, F. (ed.) 1960 Child Development: a international method of study. Modern Prob lems in Pediatrics, 45. S. Karger, Basel.

Garn, S. M., G. R. Greaney and R. W. Youn 1956 Fat thickness and growth progress du ing infancy. Human Biol., *28:* 232–250.

Garn, S. M., and C. G. Rohmann 1959 Com munalities of the ossification centers of th hand and wrist. Am. J. Phys. Anthrop., 17 319–323.

——— 1960 Variability in the order of ossifi cation of the bony centers of the hand an wrist. Ibid., *18:* 219–230.

Garn, S. M., and Z. Shamir 1958 Methods fo Research in Human Growth. C. C Thomas Springfield, Ill.

Johnson, P. O. 1949 Statistical Methods in Re search. Prentice-Hall, New York.

Lacey, J. I. 1956 The evaluation of autonomi responses: toward a general solution. Ann N. Y. Acad. Sci., *67:* 125–163.

Meredith, H. V., and E. M. Meredith 1950 An nual increment norms for ten measures of physical growth on children 4 to 8 years of age. Child Develop., *21:* 141–147.

Palmer, C. E., and L. J. Reed 1935 Anthropometric studies of individual growth. I. Human Biol., *7:* 319–334.

Palmer, C. E., R. Kawakami and L. J. Reed 1937 Anthropometric studies of individual growth. II. Child Develop., *8:* 47–61.

Reynolds, E. L. 1943 Degree of kinship and pattern of ossification. Am. J. Phys. Anthrop., *1:* 405–416.

Robinow, M. 1942 Variability of weight and height increments from birth to 6 years. Child Develop., *13:* 159–164.

mmon, R. E. 1927 The first seriatim study f human growth. Am. J. Phys. Anthrop., *10:* 29–336.

—— 1930 The measurement of the body in hildhood. In: Harris, J. A., C. M. Jackson,). G. Patterson and R. E. Scammon. The Measrement of Man. University of Minnesota 'ress, Minneapolis, pp. 173–215.

ttleworth, F. K. 1934 Standard of development in terms of increments. Child Develop., *:* 89–91.

mons, K., and T. W. Todd 1938 Growth f well children: analysis of stature and veight, 3 months to 13 years. Growth, *2:* 3–134.

tag, L. W., and J. Lipford 1943 The effect f illness and other factors on the appearance pattern of skeletal epiphyses. J. Pediat., *23:* 391–409.

Tanner, J. M. 1951 Some notes on the reporting of growth data. Human Biol., *23:* 93–159.

——— 1952 Assessment of growth and development in children. Arch. Dis. Child., *27:* 10–33.

——— 1955 Growth at Adolescence. Blackwell Scientific Publications, Oxford.

Thompson, D. W. 1944 On Growth and Form. Macmillan Co., New York.

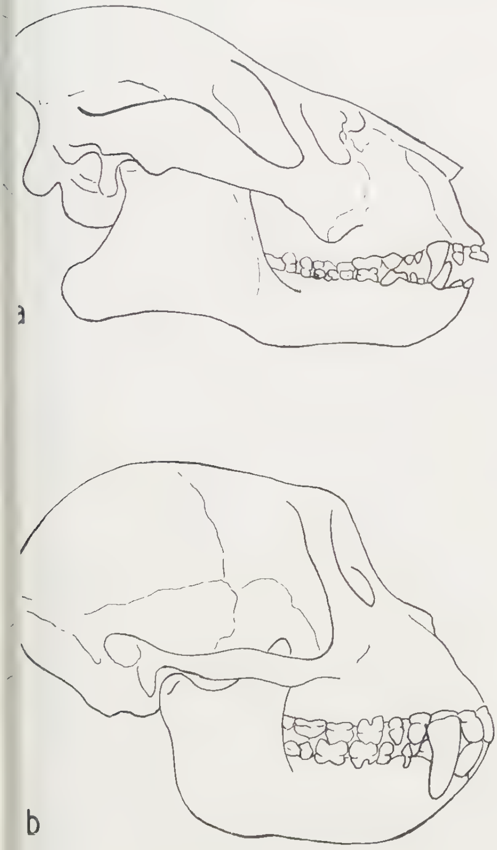
Thompson, H. 1951 Data on the growth of children during the first year after birth. Human Biol., *23:* 75–92.

Turner, C. E. 1933 Seasonal fluctuation in growth with special reference to the clothing factor. Res. Quart., *4:* 179–197.

he Significance of the Angle of the Mandible: n Experimental and Comparative Study

VIRGINIA AVIS [1]
Department of Anthropology, University of Chicago

There is a pronounced angular process
the mandible of prosimian primates.
is structure is well-developed in all mem-
rs of this group from its earliest Paleo-
ne representatives to those of the present
y. It does not occur in Old World mon-
ys or in apes. Figure 1 illustrates this
ntrast in jaw formation. A morphologi-
feature which has existed among pri-
ates for at least 65,000,000 years must
ve functional significance and adaptive
ue. This supposition is strengthened
by the fact that an angular process was a phenomenon widespread among early Tertiary mammals and also characterized even earlier, supposedly ancestral, mammalian forms as far back as the Middle Mesozoic. In Old World monkeys and apes the angle of the jaw is greatly reduced. This altered structure must represent a different kind of adaptive mechanism and this too has lasted for a great period of time—some 30,000,000 years.[2]



ig. 1 a, Adapis Magnus; b, *Macaca sp.* (from gory, '51).

The immediate purpose of this paper is to report a first step in the analysis, by experimental means, of the functional significance of the angle. The results of the experiments are used to interpret the interrelationships of form and function in the jaw. With this fuller understanding, an attempt is made to interpret the angle as it appears in the fossil record. Since this structure is present in many non-primates, a broader interpretation is included. Naturally, no single study can be definitive but it is hoped that this method of analysis, combining as it does paleontological, comparative anatomical, and experimental procedures, will make possible more and more definitive studies on the form of the face and jaws.

The initial procedure in the investigation was to determine whether or not a relationship exists between the angle and those muscles which attach to its surface. These muscles were removed from the jaws of the laboratory rat as this procedure has been shown to be an effective test (Washburn, '47). The well-developed angle of the rat made it a particularly suitable animal for the experiments. In conjunction with the operations, intra-vital injections were given to the animals in order to stain the bone. This was perhaps the first time vital staining had been combined with muscle surgery and the results obtained were of inestimable aid in interpreting the results of the experiments.

---

[1] Present Address: Department of Anthropology, University of Washington.

[2] This figure marks the beginning of the Miocene, East African forms of this time being the earliest catarrhines in which this part of the mandible is preserved (Clark, '51).

This study was financed under a grant from the Ford Foundation for the study of the evolution of behavior under the direction of S. L. Washburn.

MATERIALS AND METHODS

Operations of several types were performed under intraperitoneal pentabarbital anesthesia on male rats two to four weeks of age: (a) removal of the superficial masseter muscle (30 rats), (b) removal of the internal pterygoid muscle (37), and (c) removal of both muscles (11). All surgery was unilateral, the unoperated side of the jaw serving as control since the angle on the unoperated side failed to shown any abnormality.

Superficial masseter muscle operations. An incision extending from the angle to the orbital region, described by Pratt ('43), served to expose the muscle. All fibers of the superficial heads were removed from the zygomatic arch and mandible.[3] A few fibers of origin in the infraorbital groove were allowed to remain since their removal would have caused considerable loss of blood.

Internal pterygoid muscle operations. Removal of the internal pterygoid muscle was difficult due to hemorrhage from the pterygoid plexus of veins which lies on the deep surface of the muscle immediately adjacent to its insertion. This problem was overcome by making an oblique incision anteriorly from the angle toward the opposite side of the jaw, separating the angular process from surrounding tissues and lifting it away from underlying structures to expose the internal pterygoid muscle on its inner surface. The muscle was severed as near its origin as possible. Fibers immediately adjacent to the plexus were removed by blunt dissection and the remaining free portion of the muscle was then detached from the mandible.

Combination operations. Procedure was similar to that already described. The superficial masseter muscle was removed first in order to facilitate exposure of the internal pterygoid muscle.

Wounds were closed by interrupted sutures using Chromic 5–0 gut. The animals resumed eating within a few hours. A 2% aqueous solution of Alizarin red S dye was injected intraperitoneally on the second and third days prior to surgery or on the second to fourth post-operative days. The dosage (1 cm^3 per 100 gm of body weight) was given on two successive days to prevent a severe reaction and to give a more uniform staining. Recovery was rapid, with normal activity resumed within 24 hours. Diet consisted of hard Rockland rat pellets and wheat germ. Growth was excellent with little individual variation. The animals were sacrificed from 8–43 days after the operations.

OBSERVATIONS

Superficial masseter muscle operations. As can be seen in figure 2, the angular process was reduced in all dimensions when the superficial masseter muscle had been completely removed from the mandible. The amount of new bone on the operated angle was far less than that on the normal side. Failure to remove all fibers

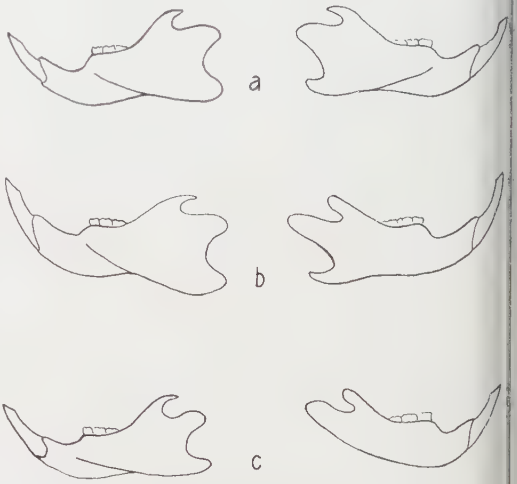


Fig. 2 Diagrammatic representation of the rat mandible before and after removal of muscles. Left, normal; right, operated. (a) internal pterygoid muscle removed; (b) superficial masseter muscle removed; (c) combination muscle removal.

---

[3] The complex masseter muscle of the rat is fully described in the excellent monograph by Greene ('35). This was an invaluable aid in planning and interpreting the experiments.

ending from the zygomatic arch to the
gle lessened the amount of reduction
the angle. The deep masseter muscle
s well-developed and apparently normal.
Gross abnormalities of the skull and
ndible did not differ significantly from
se described earlier by Pratt ('43) and
Horowitz and Shapiro ('55) for opera-
ns of this type. The altered shape of
coronoid process, as shown in figure 2,
gests that imbalance in actions involv-
the temporal muscle is reflected in the
n of its mandibular but not its cranial
achments. Rostral deviation of the skull
ard the normal side plus readjustments
he mandible to altered muscle action
ught about extreme malocclusion of the
sors, noted also by the earlier work-
[4] In the present investigation, only the
nt upper and left lower incisors habitu-
occluded. Of the other incisors (left
er and right lower), which usually
ed to meet, that in the mandible was
siderably smaller in circumference than
adjacent incisor which did occlude.
arin-staining demonstrated that growth
both incisors which failed to occlude
been minimal during the post-opera-
period. This indicates that normal in-
r growth is dependent at least in part
n normal occlusion and attrition and
, in the absence of these, the growth
is diminished. The anterior surface
he jaw, immediately adjacent to the
ll tooth, had also received much less
osition of new bone than had the op-
te normal side. This suggests that
e formation in this region depends for
mpetus upon tooth growth.

nternal pterygoid muscle operations.
e formation was minimal or lacking
he inferior border of the angular pro-
with the results illustrated in figure 2.
tal malocclusion was not apparent up-
gross examination and skeletal malfor-
ion was confined to the angular region.

ombination operations. The angular
ess was entirely absent when both
rficial masseter and internal ptery-
muscles had been removed completely
2). In those animals in which a
fibers of the internal pterygoid muscle
to be found these were associated
a tiny atypical spine of bone at the
e.

The combined use of muscle removal and alizarin-staining made it possible to demonstrate conclusively that a relationship does exist between the muscles and the size of the bone to which they attach. As figure 6 illustrates, the amount of growth that has taken place since staining can be seen and measured. This improvement in experimental procedure is possible because a sufficient dose of alizarin imparts a deep stain to all bone. Bone formed subsequently is white and easily distinguishable from that present at the time of staining. A much more precise evaluation of the differences between operated and normal jaws is obtainable. In an unstained operated mandible it is evident that the operated angle is smaller than the normal angle, but in the stained specimen it is possible to observe precisely how much new bone has been added and to determine to what extent the operated angle deviates from the normal.

DISCUSSION

The removal of the superficial masseter and internal pterygoid muscles of the rat shows that the normal postnatal development of the angular process is dependent on the presence of the muscles. A similar relationship has been demonstrated for the temporal muscle (Washburn, '47). The general relations of the parts of the mandible to the muscles of mastication in the rat are shown in figure 3. Since it

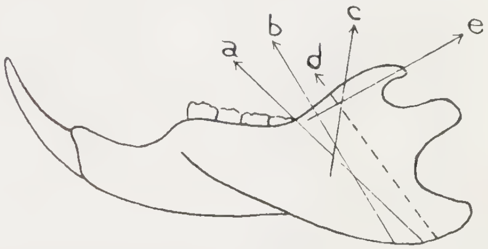


Fig. 3 Mandible of rat showing general relations of the muscles of mastication; a, anterior head, superficial masseter muscle; b, posterior head, superficial masseter muscle; c, deep masseter muscle; d, internal pterygoid muscle; e, temporal muscle.

---

[4] Persistent growth of the incisors in the rat intensifies the extensive alterations in normal jaw relationships caused by malocclusion, raising problems not pertinent to primate studies. This points up the need for an experimental animal in which such problems do not arise.

has been demonstrated (Baker, '41) that the erupting teeth are necessary for the formation of the alveolar bone this has been indicated as separate. These major divisions of the mandible are closely comparable to those suggested by Washburn ('51) for man, but the elongated, persistently growing lower incisors of the rat complicate the interpretation of the core of the mandible. Since the lower incisor of the rat is rooted in the ascending ramus, the body of the mandible is made up of both alveolar bone and the main core to which all the other functional areas are attached. This dual nature of the body is shown by the effect of lower incisor removal (Baker, '41) and by the effect of growth hormone, which accelerates growth in length (Baume et al., '53).

The fact that the various parts of the mandible may vary independently to a considerable extent may be demonstrated experimentally, comparatively, or by the study of the growing mandible. However, the independence of the parts should not obscure the fact that, under normal conditions, the parts form an integrated whole, a working complex. Operations, at least those involving the superficial masseter muscle, disturb the normal balance and are followed by the changes noted in this and earlier papers (Pratt, '43; Horowitz and Shapiro, '55). Most of these differences appear to be due to altered use and muscular imbalance, but they do illustrate that limited interdependence of the parts exists. However, considering the major character of the operations, the degree of independence is the principal finding.

All of the parts of the mandible which are indicated as separate in figure 4 are self-differentiating in the embryo (Bhaskar, '53). A normal coronoid process, angular region, and the beginnings of alveolar bone are present at birth and there is no indication that the basic plan of the jaw is due to anything but inherent genetic factors. The transplanted mandible will continue to develop for as long as 40 days (Baker, '41); but continued postnatal growth is dependent on the normal relations of bone, muscles and teeth. The statements that (a) the angular region is self-differentiating and that (b) it is dependent on the functioning of the muscles which attach to it are both correct but apply to different parts of the growth cycle. The bone which is present in the adult is that which has been maintained by the functioning muscles.

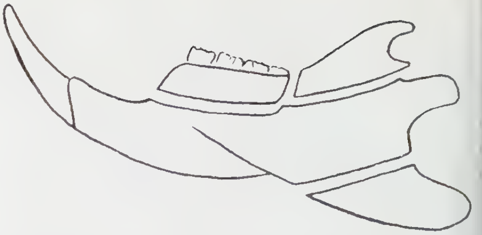


Fig. 4 Diagrammatic representation of the main functional areas of the mandible of the rat.

The role of these muscles in the jaw complex can be surmised by anatomico-mechanical analysis (fig. 3). To test this experimentally the superficial massete muscle was removed bilaterally in a series of 21-day rats. Results demonstrated conclusively that apposition of the incisors was severely restricted by reducing the power which could be brought to bear on an object held between the teeth. Experimental work on this score was not attempted on the internal pterygoid muscle owing to the difficulty of bilateral removal. However, anatomico-mechanical analysis indicates that its possibilities for action are similar to those of the other muscle.[5]

Because prosimians, both fossil and modern, share with the rat well-developed front teeth and shallow jaws with an angular process, it is believed that their bone-muscle-tooth complex should function in much the same manner. Among living forms the aye-aye even has rodent-like incisors. All remaining modern prosimians except the tarsier have procumbent lower incisors. These are part of an important adaptive complex in shallow-jawed prosim

---

[5] The superficial masseter muscle is undoubtedly much more important in incisor apposition i.e., gnawing, in the rat as shown by its fa greater size and by the greater effect of its removal. This use may account for the elaboration of the superficial masseter in rodents (Parsons 1896).

ns.[6] Among modern sheep, cattle, and
er the lower jaw with procumbent lower
cisors works against the upper lip, serv-
g as a mechanism for cutting vegetation.
insectivores and tree shrews there seems
be a comparable adaptation in which the
ver incisors are used against the back
the upper incisors. This shows the use
procumbent lower incisors for cropping
ether apposed to an upper lip or to upper
cisors. All lines of evidence suggest that
many mammals procumbent lower in-
ors were evolved as a cropping and cut-
g adaptation with the forward and up-
rd motion of the jaw in these forms ac-
nplished by the superficial masseter and
ernal pterygoid muscles attached, if the
v is shallow, to an enlarged angular
ion.

The significance of the angle is not the
gle as such but is the bone-muscle com-
x and the functioning that this makes
ssible. Therefore, in interpreting the
ferences between forms in which it is
sent or absent, an analysis must be
de of the whole jaw complex. This is
erently complex and more difficult than
nonstrating the relationship of bone to
iscle. In order to simplify the compari-
n, it will be limited to a lemur and an
d World monkey. After contrasting these
o forms we will discuss the extent to
ich they are representative of lemurs
d monkeys in general. Figures 5a-b
ow a comparison of the lemur mandible
d that of a monkey. The actions of the
iscles have been indicated by arrows.
will be seen that, as the jaw becomes
eper, the superficial masseter-internal
rygoid muscles become more of an ele-
or and less of a protruder of the jaw.
e possible interpretation of the changes
m lemur to monkey is that, when the
ndible became deeper, correlated with
ger molar teeth and a more efficient

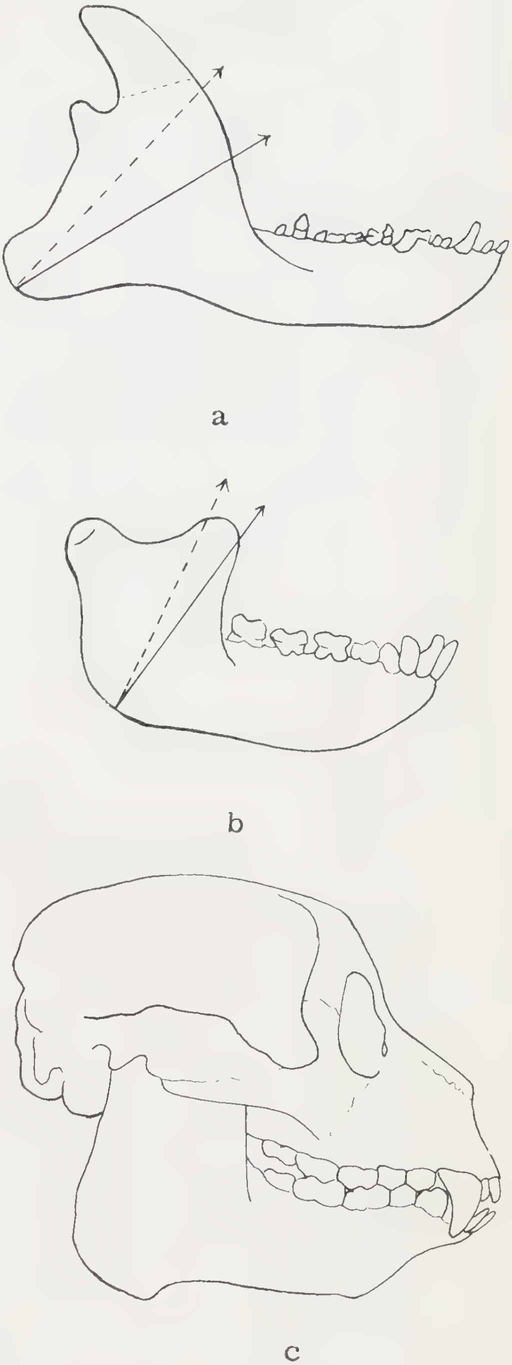


Fig. 5 a, Mandible of Adapis Magnus; b, mandible of *Macaca sp.;* c, Mesopropithecus. Solid lines, superficial masseter muscle; dotted lines, internal pterygoid muscle. (a and b modified from Gregory, '51; c, from Piveteau, '57).

---

[6] It has been suggested that this typical modern
m is an adaptation for grooming (Wood Jones,
). Since the fur is cleaned largely if not en-
ly by the tongue it is highly improbable that
h an elaborate complex has been evolved solely
this purpose. It had earlier been suggested
Gregory ('20) that the enlargement of the
gue and its protrusibility had resulted in the
ward tilt or thrust of the front teeth. Large
l protrusible tongues in other mammals have
had such an effect, so this explanation is
n less acceptable.

grinding apparatus, the higher ascending ramus was incompatible with the lemuroid type of angular process. The typical lemuroid process occurs in a shallow jaw and the process extends well posterior to the condyle. The fibers of the superficial masseter and internal pterygoid muscles are nearly parallel to the horizontal ramus. If a lemur jaw is fitted onto a monkey skull it will be seen that this type of jaw-muscle complex will not operate properly on the monkey skull.

If the simplified analysis given by the comparison of lemur and monkey is correct, then the smallest angular regions in the lemurs should occur among the lemurs with the deepest jaws. This prediction is verified as seen in Paleopropithecus, Megaladapis, and Mesopropithecus, the latter being shown in figure 5c. This short-faced, deep-jawed lemur, Mesopropithecus, has the most monkey-like mandible (Piveteau, '57). If this line of reasoning is correct, then the nearest approach to a lemuroid angle among the monkeys should occur in shallow-jawed monkeys and this condition can be seen best in certain marmosets.

Although the change in depth of the jaw appears to be the most important factor leading to a loss of the lemuroid angle, it is obvious that there are exceptions to the generalization and that additional factors must be considered. In certain lemurs of moderate size, e.g., Propithecus, the angular region is much better developed than in Old World monkeys. This difference appears to be related to the procumbent lower incisors, protrusion of the jaws and a different masticatory complex. It is to b noted that many of the primitive mammal were shallow-jawed and had well-develope angles. Against this broad background o primitive mammalian structure one see the lemurs as a special case retaining th primitive features and the monkeys as on of the numerous lines of evolution to deeper jaws and larger teeth.

In man, much of the primitive masticatory pattern of muscle action is stil maintained, as shown by electromyographic studies (Carlsöö, '52, '56; Moyers '50). Clinical work also reveals an intimat connection between bone formation an maintenance and the attached muscle (Rogers and Applebaum, '41; Masters et al. '55). However, it is quite probable tha with the deepening of the jaws in monkeys, apes, and man, and the consequentl less mechanically-advantageous position o the superficial masseter-internal pterygoi muscle complex, the external pterygoi muscle took over much of its former function as protruder of the jaw. This ma explain variations in the development o the external pterygoid muscle.

These speculations depart widely from the immediate conclusions of the experiments on the rat. Nevertheless, the thinking that lies behind them springs from these experiments and is partially supported by them. If one thinks of the face as a bone-tooth-muscle complex, then its evolution is interpreted as the changing relations of the smaller complexes. The angle of the jaw appears not as bone only

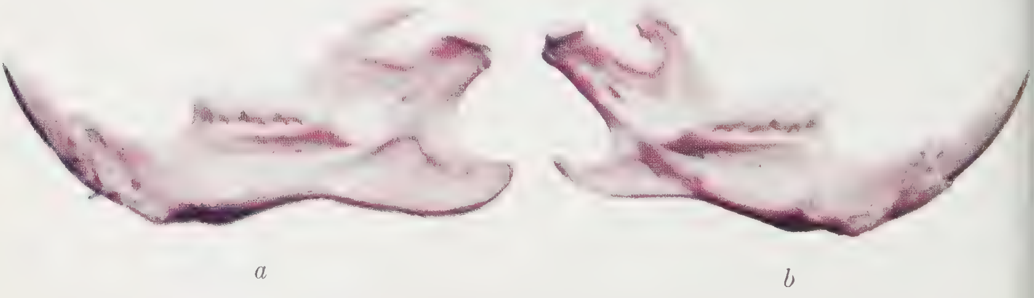


Fig. 6 Internal view of the mandible of a three-months-old rat two months after removal of the superficial masseter muscle and injection of Alizarin red S. The bone present at the time of the operation and injection is stained red. Bone formed subsequently is white. The alizarin outline of the original mandible is especially visible in the coronoid, condyloid and angular processes. a, normal side; b, operated side. Approximately × 2.

ut as an indicator of muscle, motion, and ay of life.

SUMMARY

1. The superficial masseter and internal terygoid muscles were removed unilater- lly in a series of young rats.

2. The rats were injected intraperito- eally with a 2% solution of Alizarin red S ye just prior to or just after surgery.

3. The angular process was greatly re- uced in all dimensions when either the iperficial masseter muscle or the internal terygoid muscle was completely removed.

4. The angular process was entirely ab- ent when both the superficial masseter nd internal pterygoid muscles were com- letely removed.

5. Alizarin-staining aided in compari- on of operated and normal jaws by mak- ig it possible to see the locale of and to neasure precisely the amount of post-oper- ive bone growth.

6. The findings support the theory that ie jaw is composed of a number of rela- ively independent parts which vary ac- ording to their functions.

7. The angle is directly related to the inctions of the superficial masseter and iternal pterygoid muscles.

8. The evolutionary significance of these ndings was discussed.

LITERATURE CITED

aker, L. W. 1941 The influence of the formative dental organs on the growth of the bones of the face. Am. J. Orthodontics, *27:* 489–506.

aume, L. J., H. Becks and H. M. Evans 1953 Growth and transformation of the mandibular joint in the rat thyroidectomized at birth. VII. The effect of growth hormone and thyroxin given separately or in combination. Ibid., *39:* 623–633.

haskar, S. N. 1953 Growth pattern of the rat mandible from 13 days insemination age to 30 days after birth. Am. J. Anat., *92:* 1–53.

Carlsöö, S. 1952 Nervous coordination and mechanical function of the mandibular elevators. Acta Odon. Scan., *10:* Supplementum 11, Stockholm.

——— 1956 An electromyographic study of the activity, and an anatomic analysis of the mechanics of the lateral pterygoid muscle. Acta Anat., *26:* 339–348.

Clark, W. E. Le Gros 1951 The Miocene Hominoidea of East Africa. No. 1, British Museum (Nat. Hist.).

Greene, E. C. 1935 Anatomy of the rat. Trans. Amer. Phil. Soc., No. 27, Philadelphia.

Gregory, W. K. 1920 On the structure and relations of *Notharctus*, an American Eocene primate. Mem. Amer. Mus. Nat. Hist., N.S. *3:* (part 2) 51–243.

——— 1951 Evolution Emerging. The Macmillan Company, New York, 2 vols.

Horowitz, S. L., and H. H. Shapiro 1955 Modification of skull and jaw architecture following removal of the masseter muscle in the rat. Am. J. Phys. Anthrop., *13:* 301–308.

Masters, F., N. Georgiade and K. Pickrell 1955 The surgical treatment of benign masseteric hypertrophy. Plast. Reconstr. Surg., *15:* 215–221.

Moyers, R. E. 1950 An electromyographic analysis of certain muscles involved in temporomandibular movement. Am. J. Orthodontics, *36:* 481–515.

Parsons, F. G. 1896 An account of the myology of the Myomorpha, together with a comparison of the muscles of the various suborders of rodents. Proc. Zool. Soc. London, 159–192.

Piveteau, J. 1957 Traite de paleontologie, Tome VII: Primates. Paleontologie Humaine. Masson et Cie., Paris.

Pratt, L. W. 1943 Experimental masseterectomy in the laboratory rat. J. Mamm., *24:* 204–211.

Rogers, W. M., and E. Applebaum 1941 Changes in the mandible following closure of the bite with particular reference to edentulous patients. J. Am. Dent. Assoc., *28:* 1573–1586.

Washburn, S. L. 1947 The relation of the temporal muscle to the form of the skull. Anat. Rec., *99:* 239–248.

——— 1951 The new physical anthropology. Trans. N. Y. Acad. Sci., Ser. 2, *13:* 298–304.

Wood Jones, F. 1929 Man's Place Among the Mammals. Longmans, Green and Company, New York.

ansplantation Studies of Factors in
eletal Organogenesis

THE RESPONSE OF THE IMMATURE MOUSE HUMERUS TO LONGITUDINAL COMPRESSIVE FORCE[1]

JAMES W. MONSON[2] AND WILLIAM J. L. FELTS
Department of Anatomy, University of Minnesota,
Minneapolis, Minnesota

n the first paper in this series (Felts,
) we presented observations on the re-
nse of early postnatal rat and mouse
g bones to removal from the limb en-
nment and placement in the subcu-
eous site. It was emphasized that—
the embryonic rudiment cultivated
itro (see Fell, '56, for summary review
skeletal organ culture)—such postem-
onic, cartilage-preceded skeletal organs
ibit remarkable autonomy, i.e., there is
ck of dependency upon functional con-
ons for attainment of gross size and
pe. On the other hand, it was clear
t formation and maintenance of spe-
topographical features are dependent
n conditions in the developing limb.
se findings lead to the conclusion that
gross morphogenesis of cartilage-pre-
ed skeletal organs, from embryonic
iment to definitive adult stage, is a
ction of the pattern of rates and di-
ions of growth and maturation estab-
ed at the differentiation of the cartilage
del and operable until only articular
ilage remains. This inherent pattern
ermines both overall form and the oc-
rence and progress of ossification, and
the substrate for action of local modi-
ig compressions and tensions of the
b environment.

n view of the generally excellent
wth attainment of the free implant
the ease of approach to the subcu-
eous site, it would appear that this is
uitable system with which to investi-
a problem of extreme importance to
se who are interested in bone growth
development; that is, the manner in
ch developing skeletal organs respond
to known artificial force application, and, as a corollary, the analysis of the force exerted by the growth of an organ within a system. For many years, practitioners of orthopedics, orthodontics and allied specialties have used—with some apparent success—clinical procedures to limit or stimulate growth of skeletal parts. In general, these methods are the result of a variable and often insufficient amount of basic experimentation and a good deal of trial and error. Chief among the problems involved is the question of the magnitude and duration of force which will influence elongation, as well as other growth processes, of long bones at various ontogenetic levels. In spite of a large number of investigations on the mechanical control of growth at one or another epiphyseal line (e.g., Haas, '45; Blount and Clarke, '49; Gelbke, '51; Strobino, French and Colonna, '52 and Siffert, '56), the picture is far from clear and, more fundamentally, the whole-organ response to known forces is virtually unknown. Indeed, there has been—to our knowledge—but one study dealing specifically with the effects of mechanical forces on early growth of whole long bones (Glucksmann, '38, '39, '42), and that a non-quantitative one with early embryonic rudiments *in vitro*.

A basic concept derived from the literature is that skeletal organ configuration is influenced by two sets of factors, the

---

[1] Supported by grant A-1104, P.H.S., National Institute for Arthritis and Metabolic Diseases.

[2] Present address: Division of Orthodontics, School of Dentistry, University of Minnesota, Minneapolis, Minn.

intrinsic or inherent which alone are capable of producing certain recognized characteristics of a given bone and the extrinsic which act in the immediate and more distant environment during normal development. One may say that normally the intrinsic and extrinsic factors work in harmony to produce, respectively, the basic plan and the specific refinements of bone shape, but at times the extrinsic are opposed to the intrinsic—as in cases of altered function or pathologies. In order to produce recognizable alterations in bone form, there must not only be opposition of these factors, but the extrinsic must additionally be strong enough to exceed what, for simplicity, may be called the physiological limit of the developing organ and of its constituent tissues. Obviously, the term "physiological limit" is as flexible in definition as it is (at least temporarily) useful. However, in terms of this investigation, we suggest it as the point beyond which, under external forces, the developmental mosaic of cartilage, bone and germinative tissue, as a whole, does not maintain essential spatial relationships or the components their expected interrelation of individual rates and directions of growth and maturation. We shall return to this point in our conclusion.

This experiment, in essence, consists of the application of one measurable extrinsic factor — longitudinal compressive force—to whole growing bones under conditions that preclude normal muscular and postural functions. As a technique, we developed simple wire appliances which were implanted subcutaneously with the early postnatal mouse humerus and resulted in the creation of force as the bones grew. More specifically, the implant was so situated that its longitudinal growth and the physical characteristics of its tissues would determine the rate and extent of deflection of a half-circle of wire; the tendency of the wire to return to its original conformation exerted a compressive force against the ends of the bone. It was hoped that such a relatively simple approach might lead to an understanding of the reactivity of size, shape and maturation in osseous and cartilagenous components of whole long bones at nearly the earliest accessible stage of postembryonic development. This paper reports on one such experimental series and, it is our hope, may suggest other applications of the technique.

In the previous paper we reviewed the history of *in vivo* culturing or implanting of entire bones or major portions thereof Rather than repeat such a survey *per se* earlier investigations will be referred to where pertinent to the discussion, as will the very restricted germane literature concerning mechanical influences upon growing bones.

MATERIALS AND METHODS

The series reported here consisted of humeri of neonatal mice, implanted with or without a compression appliance in adults of the same inbred BALB/c strain. The implants were, therefore isologous (intrastrain) and experienced no adverse reaction from the host (Felts, '57b). Operative procedures were as reported in detail in earlier papers. Humeri were removed from the two-day donors with the aid of suitable microdissection instruments and a stereoscopic microscope. Care was taken not to injure cartilage, bone or the germinative tissues and, after measurement with a vernier ocular micrometer, specimens were placed in isotonic saline until the immediate group was collected. The compression appliance was fitted to the desired proportion of the bones in the saline and—after further measurements of the appliance and bone—two bones with appliances and one without were inserted into the subcutaneous tissues of each host via incisions in the dorsal lumbar skin. In all, 72 implants were produced, with 48 in appliances and 24 as free implants. Four implants with appliances and two without were collected from hosts after periods of 5, 10, 15, 20 and at 10 day intervals through 60, then 75, 100, 150, and 200 days (two hosts for each interval). For comparison, two unimplanted humeri were collected from colony animals for each age interval.

The appliance, as developed after considerable experimentation, is illustrated in figures 1 and 2. Stainless-steel wire, 0.011″ diameter and heat-treated for maximum resiliency, was bent around a jig into semicircles approximately 6 mm in

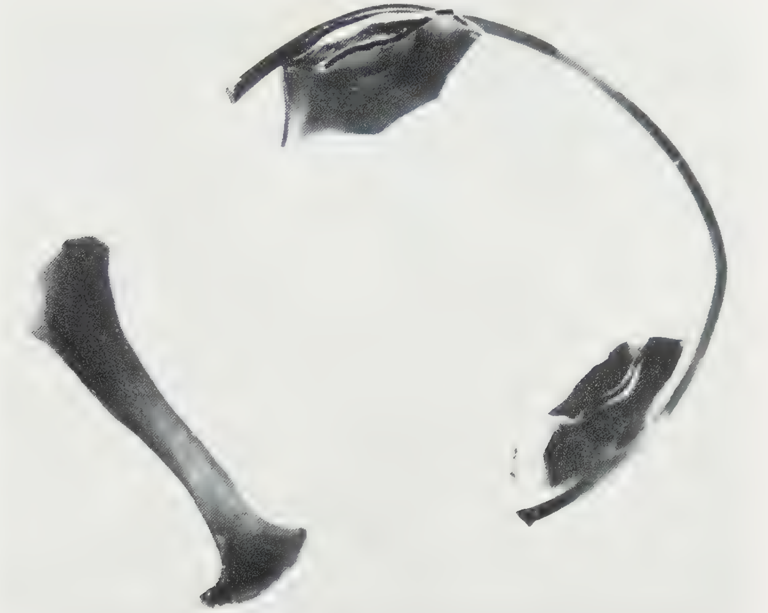


Fig. 1 Photomacrograph of recovered appliance and compressed implant of 50-days duration. Appliance has been deformed manually in removing implant for clearing. Note the position and concavity of the sheet steel end-plates. Approximately 8 × natural size.

diameter. Inside the ends of these wires, small saucer-shaped discs (0.006″ stainless-steel plate approximately 3 mm in diameter) were secured by use of an orthodontic electrowelder. These discs served to hold the humerus in position. Because the bones varied slightly in length, each appliance had to be adjusted, by bending of the wire semicircle, to just hold the bone passively.

Before using the appliance it was necessary to determine the amount of force associated with a given deflection. With this factor known, as well as the diameter of the appliance at the time of insertion in and removal from the host, the amount of force under which the implant existed could be calculated. For this calibration, each appliance was suspended by one of its discs before a horizontal dissecting microscope equipped with a vernier ocular micrometer, and its outside diameter (weld to weld) was determined (fig. 2). Weights then were suspended from the other disc and the deflection for each weight (force) increment (1, 2, 5, 10, 20 and 20 grams) was measured. All appliances were so calibrated and mean values were used to construct the graph in figure 3; from the curve obtained, the force-deflection relationship was determined.

When the implants were removed from the host, the outside diameter of the appliances were again measured and subsequently compared with the initial measurements. The force produced by elongation of the bone was then found by reading the correct gram value for the known deflection (fig. 3). It is our opinion that there were no significant biological factors acting to jeopardize the correct functional relationship between growing bone and flexible wire. Over the whole series, it was found that the wire-humerus complex was no more adherent to or restricted by surrounding tissues than were the free implants. (In early test implantations, it was found that rolling-in of the edges of the discs prevented the appliance from "digging in" in the surrounding tissues.)

When removed from the host, and after measurement, both types of implants were

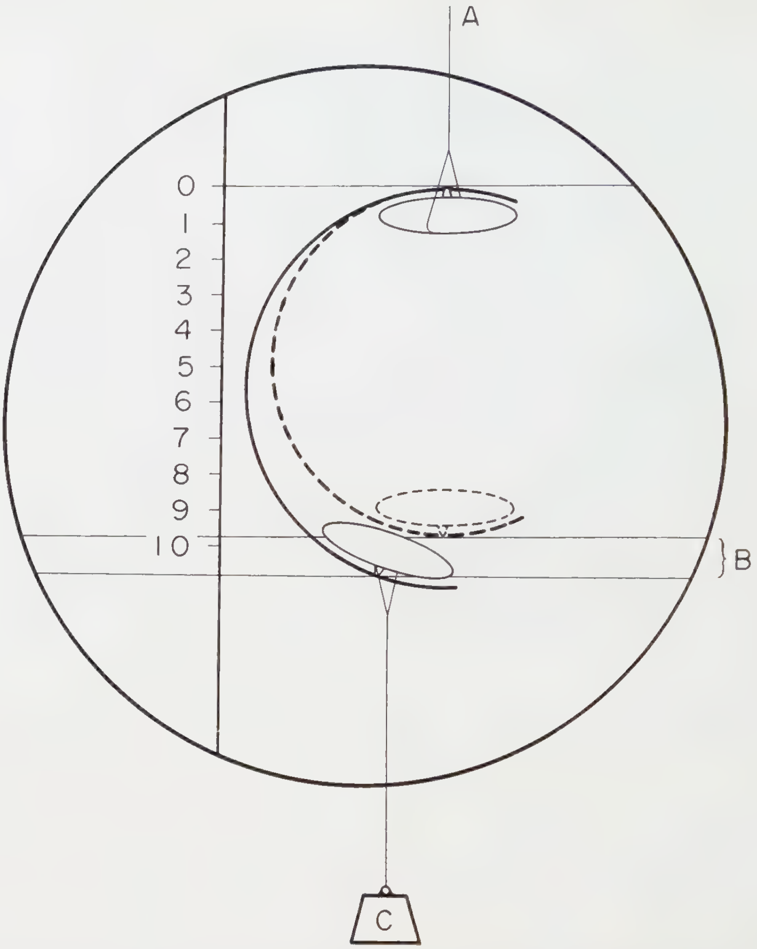


Fig. 2 Illustration of technique for measurement of deflection of appliance under known loads. View is that which would be seen through horizontally-orientated dissection microscope eyepiece (outer ring). A is the upper wire support of appliance, C is weight suspended from lower end-plate. B represents the measurable deflection with the given weight. The vertical scale is that of the ocular micrometer.

fixed in formalin. Those of each group to be studied as whole-mounts were cleared in KOH (with alizarin Red S added) followed by glycerin. Others were decalcified and processed for histological sectioning. These procedures, as well as the particular photographic and illustrative techniques, have been used in our previous studies (Felts, '57a, '57b, '59).

OBSERVATIONS

The free implant. The behavior of the free humeral implant when removed from the limb and placed in the subcutaneous site affords a point of comparison with those in appliances and, at the same time, an opportunity to restate certain generalities established in earlier papers. In all essentials, growth and maturation of such humeri (here and in earlier experiments) parallels the results obtained by others who have worked with such transplants of whole bones or major portions thereof (e.g., Willis, embryonic long bones in rat brain, '36; Barnicot, '41 and Gillette et al., '57, parts of tibiae and ribs; Crelin, rib parts and pelvic halves, '54).

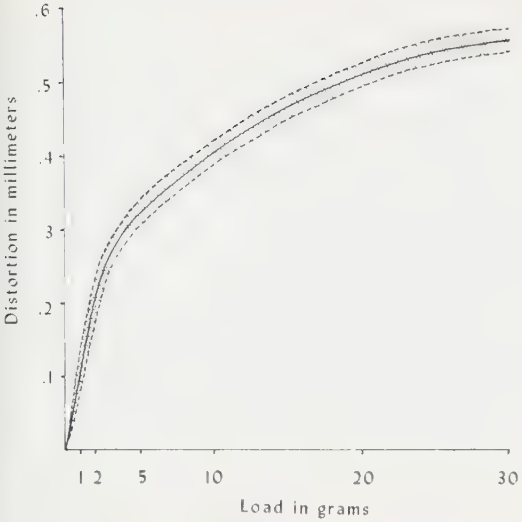


Fig. 3 The relationship of load increment (under conditions depicted in figure 2) to distortion or deflection of the appliances to loads of 1, 2, 5, 10, 20 and 30 gm was determined and mean values were used in construction of this graph. The shaded area indicates one S. D. about each mean and all three lines were drawn freehand through plotted points.

When placed in the subcutaneous pocket, the multitissue implant is subjected, obviously, to a short period of avascularity followed by a period of progressive revascularization. The diffusion of tissue fluids constitutes a minimal metabolic requirement during the early period, but total revascularization must occur in time to assure continuous vitality of the tissue with the greatest metabolic demands (i.e., marrow with its osteogenetic component). If, for any of a number of biological and mechanical reasons, revascularization is delayed, the several tissues will succumb in the order of their dependency upon vascular sufficiency: marrow, bone, periosteum and cartilage (Felts, '57a). Any series of whole bone implants evidences morphological consequences of the early avascular period and of varying rates and degrees of revascularization. This fact is well exemplified by our present free humeral series (fig. 4, bottom row), about which several general statements may be made. First, no evidence of ossification is encountered until, usually, the 5th day, at which time new bone may be recognized at the ends of the original shaft. Such bone, lying superficial to a deeper, marrow-filled erosion of cartilage, precedes slightly the re-establishment of periosteal deposition (fig. 4). Second, the formation of secondary centers of ossification is delayed. In the normal condition, the proximal and distal centers appear at about the same time, 5 to 6 days after birth. In the implanted humerus (fig. 4, second specimen in bottom row), the first center to appear is typically the distal one, at 9 to 11 days postimplantation (i.e., 11 to 13 days postnatal and, thus, 5 to 7 days late). However, once the specific pattern of primary and secondary centers is established, the normal course is run with relative contributions to elongation and timing of epiphyseal closure as in the normal (figs. 4 and 5, 4th specimen). Third, implants are generally wider across the ends, relative to length, and are not, ultimately, as long as normal bones. This condition may perhaps be attributed to a continuous suboptimal circulation to the deep epiphyseal cartilage while peripheral circulation is adequate for increase in width around its circumference.

In addition to confirming the results of our earlier studies (Felts, '59) regarding over-all morphogenetic attainment, the humeral implants (including the compression series in this aspect) show the same loss of surface details, such as articular topography and the humeral spine. The progressive disappearance of the spine is most noticeable and is doubtlessly due to its submergence in periosteal depositions not acted upon by specific muscles. The same explanation serves for other bony landmarks, already formed, and the proliferation of surface cells similarly may account for obliteration of articular details in cartilage. In the free implants, the pressure of overlying dermis and underlying muscle causes some anteroposterior flattening and directs periosteal activity in such a way as to hasten the spread of new bone over the spine region. (In the compression series, the appliance tended to protect the humerus against this pressure and shaft details disappeared more slowly on a more rounded shaft.) The failure of appearance of certain features normally developing in the period

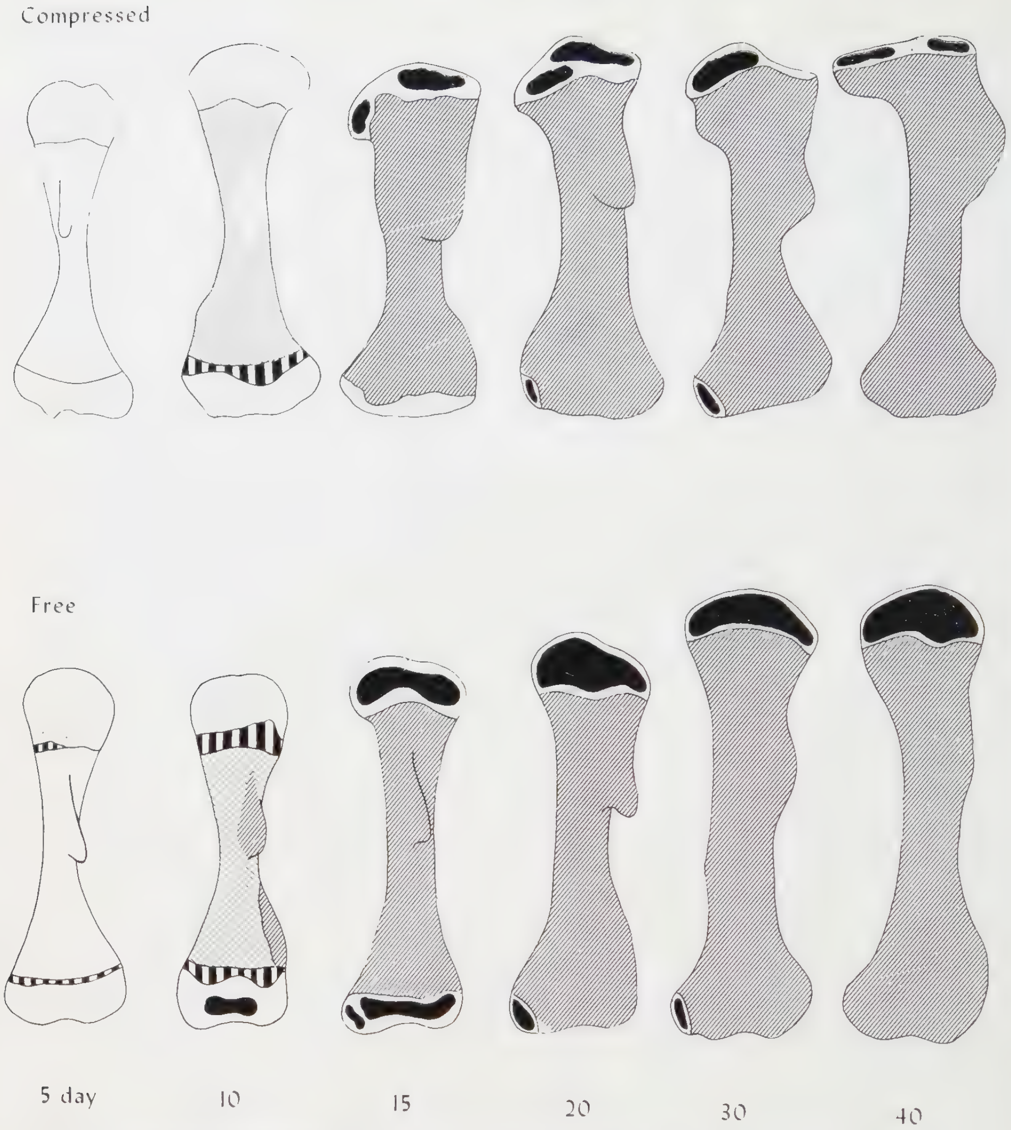


Fig. 4 Drawings of representative bones from the experimental (compression) and control (free) series. Cartilage is shown as stipple, original shaft bone as white, new periosteal bone as diagonal lines (light for early fine distribution, heavy for later uniform bone), and heavy vertical lines depict the distribution of the early osteogenetic replacement of cartilage beyond the ends of the original shaft. 8 × natural size.

of two weeks to a month (e.g., olecranon foramen and epicondylar crest) (fig. 5, first and 5th specimens) is due obviously to absence of functional relationships (Felts, '59).

The implant under compression. Figure 4 compares representative specimens taken from each age group of the free and compression series. When examining this figure one should bear in mind that it is a sequence of drawings of individual bones allowed to develop for the specified periods rather than a record of the development of single bones. The humeri were chosen from those collected because they were either representative of or me-

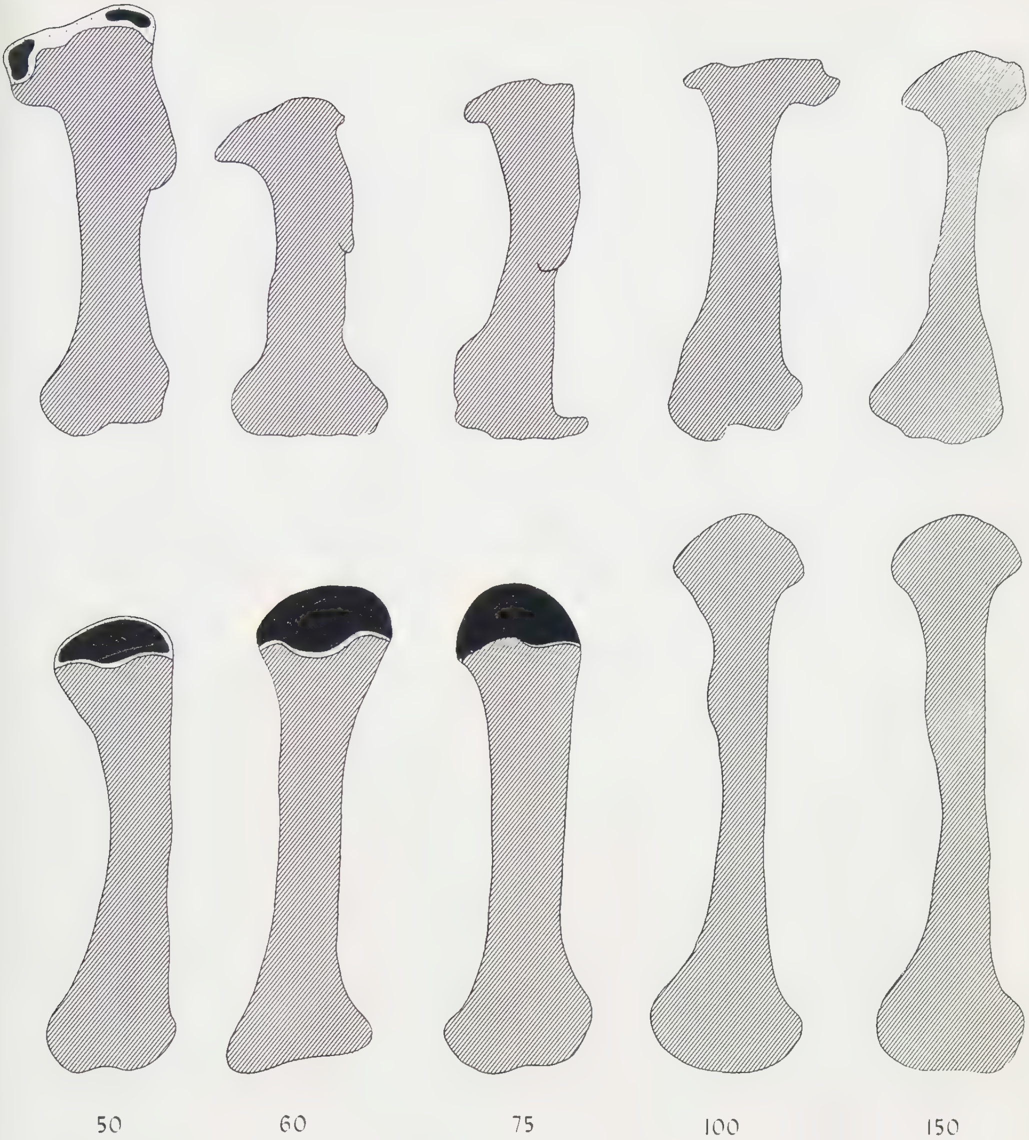


Figure 4 (*Continued*)

dian in the group and, therefore, both individual and small-group characteristics are evident. An example of this condition is the 10-day humerus in the compression series; the distal center is not developed but the general configuration of the bone was ideally median in its group. Another unfortunate experimental condition is illustrated in the 50- and 60-day compressed bones; the first is inordinately large, the second quite small and somewhat bent at the proximal end. Both were the best among the reduced numbers collected for those advanced periods. This produces a sharp break in the series that is not borne out in further examination.

Systematic examination of figures 4 and 5 establishes critical differences of size and shape between compression and free series. Although, as already noted, implants are consistently shorter than normal bones, a free humeral implant will

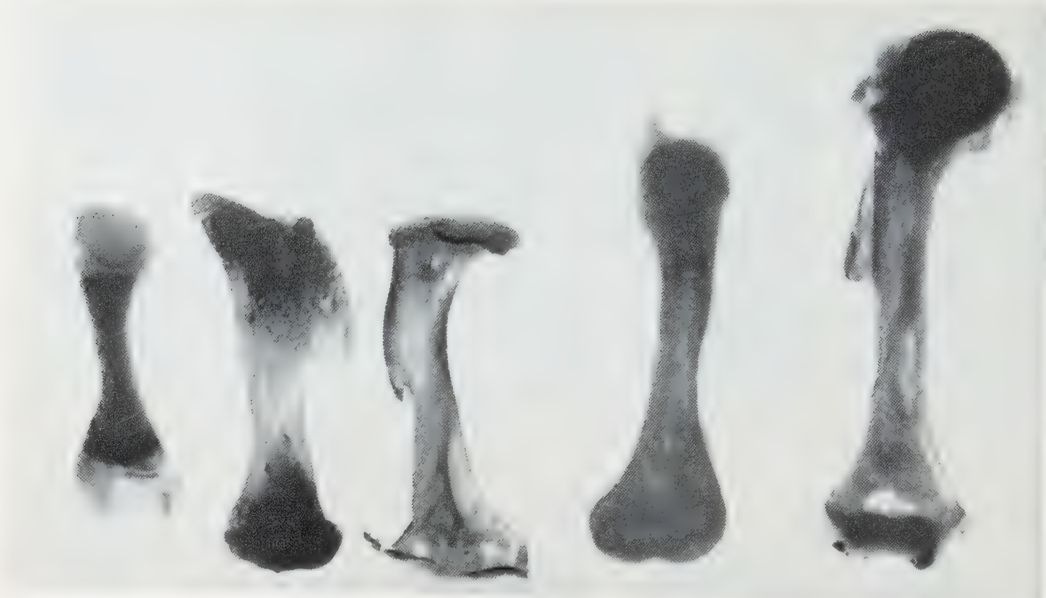


Fig. 5 A series of normal, free, and compressed mouse humeri. From left to right: two-day normal (typical of humeri when implanted; 40-day compressed; 75-day compressed; the most extreme case of end flattening encountered) 20-day free (uncompressed) implant; 21-day normal humerus. Specimens have been cleared and stained, and photographed by transmitted and incident light while in glycerin. Approximately 8 × natural size.

increase in length from about 5.5 mm at two days to 8.5 mm (55% increase) at 100 days while a compressed humerus of the same age has not been found longer than approximately 6 mm (9% increase). Compressed implants show progressive flattening against the appliance and widening across the proximal and distal ends (especially the former) but the center sections of the bony shafts generally match those of the free implants. Maturation, as indicated by the appearance of secondary centers and by epiphyseal closure, proceeded at essentially the same rate in both series until advanced stages were reached. Both series displayed the same reduction in the middle region of the shaft (100- and 150-day specimens in fig. 4) once growth was completed; the feature has been noted in earlier studies with humeri and phalanges (Felts, '59) and its unexpected occurrence in the compressed series will be discussed later.

The inherent timing of ossification in the proximal and distal cartilages is an important factor in whole-organ response to the accumulative load. In this experiment, the distal center developed during the period when elongation was just underway and the force was below the load limit of the cartilage masses. Ossification advanced therefore into a relatively distortion-free cartilage and the fusion of this body to the shaft (on schedule) occurred before gross deformation was possible. During the later period of most active elongation and, thus, the greatest rate of loading by the appliance, the proximal cartilage (initially retarded and inherently of a prolonged growth period) came to manifest the greatest deformation (fig. 5 second specimen). A most obvious characteristic of the proximal end of the compression humeri (fig. 4) is the absence of the central region of the secondary center; this is most likely attributable to impaired nutrition immediately under the central region of the restraining plate.

Cessation of growth, as indicated by proximal epiphyseal closure (observed on cleared specimens under a high-power dissecting microscope), occurred earlier in the compressed than in the free series, at 60 rather than 75 days. The ends of compressed bones of this age and beyond are obviously distorted and, for that matter, the proximal secondary center shows progressive flattening within the deforming cartilage from as early as 20 days and on. It has been a general observation that distortion of shafts is in evidence only in regions where ossification has replaced deformed cartilage and that angular deflections are present in these regions only when bones are not well-seated in the appliances and consequently do not receive the compressive force along the long axis. An example of this is shown in figure 6.

In attempting to correlate morphogenesis and maturation of the implant (fig. 4) with deflection of the appliance (fig. 3), it is useful to think of the relationship as having three successive phases. A diagrammatic representation of this division is presented in figure 7 and should be compared with the curve for length increase in figure 8. It should be realized that here, as in any arbitrary but reasonable division of a biological continuum, there is actually a gradual transition from one phase to another, and individual variations must be reckoned with.

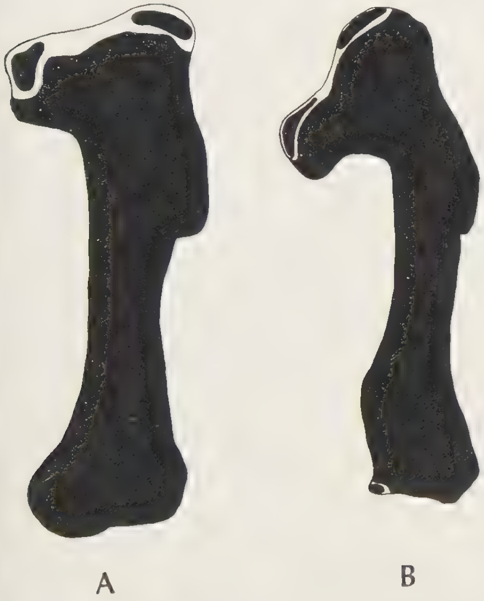


Fig. 6 A comparison of two 50-day compressed humeral implants. A was properly orientated in the appliance and is typical of the experimental series. B represents a case in which the implant was originally, or later became, poorly seated in the appliance and the longitudinal force was not directed along the long axis. Bone is indicated by black, cartilage by white. Angular distortion has occurred beyond the ends of the original bony shaft (see text).

The *first phase* (fig. 7, *1*) includes the period of revascularization and the first evident growth of the humerus within the appliance. This covers the first 10 days after implantation, with an osteogenesis-sustaining revascularization usually complete by 6–7 days. The experimental humerus is wholly comparable to the free implant and the slight increase in length late in this phase brings it into tight fit with the appliance. The *second phase* (fig. 7, 2) covering the period of 10–15 days after implantation, is one in which elongation of the humerus causes obvious deflection of the wire appliance. This results in a longitudinal compressive force upon the implant, but, for the greater part of this phase, the force is not of such magnitude as to result in gross deformation of the cartilage mass. In the *third phase* (fig. 7, 3), beyond approximately 15 days after implantation, the load limit for the cartilage mass is reached and elongation slows drastically, then ceases. This does not imply that cartilage tissue growth (as opposed to organ elongation) ceases at once, for subsequent proliferation spreads cartilage out against the endplate. Late in the second phase and in the third, as bony tissue replaces the deformed cartilage, the definitive bone assumes that deformity. As indicated earlier, this process is a function primarily of the proximal cartilage because the distal is replaced by bone before the large deforming loads have accumulated. Late in this phase, deformation of bone at both ends becomes obvious (fig. 5, third specimen).

The determination of the force produced. The *force* produced by the resilient wire appliance is equal and opposite to that produced by the elongating cartilage; by reference to the empirical force/deflection curve (fig. 3) it is possible to ascertain this growth force in any given implant. Such simple force determinations are presented in table 1, based on the mean deflections for appliances collected from 5 to 150 days after implantation. Com-

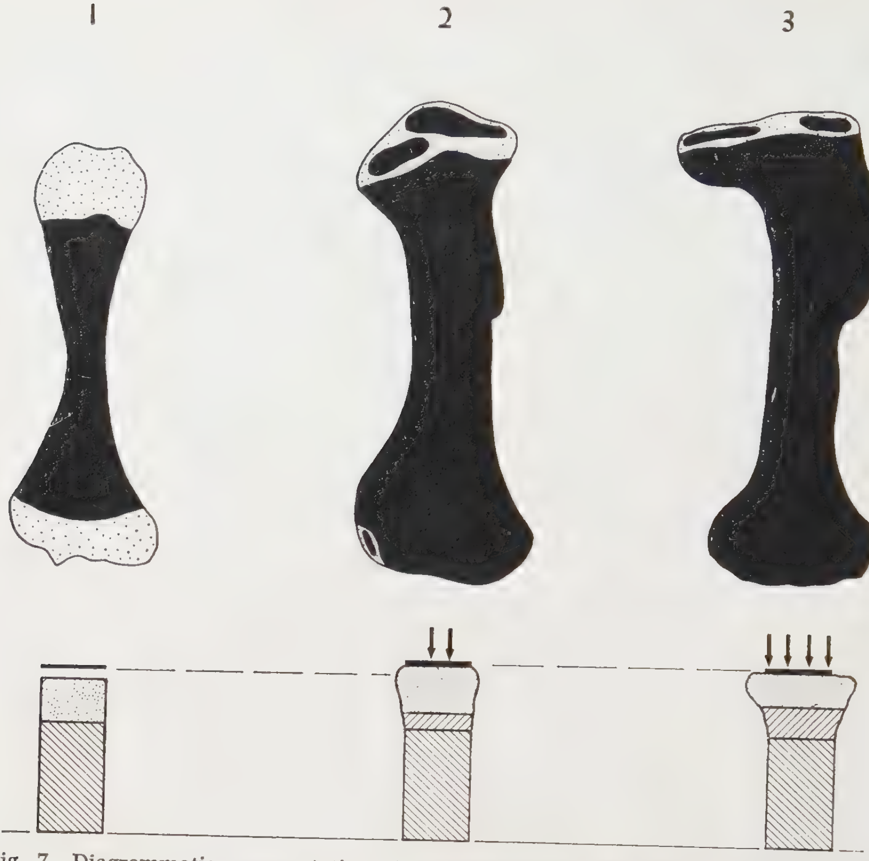


Fig. 7 Diagrammatic representation of the three phases of implant response to the force produced by growth against the appliance. The upper row of figures indicates that morphogenetic levels associated with the early period (1) of revascularization and fitting to the appliance, the phase (2) in which the implant grows against the appliance, and deflects it, and the later phase (3) in which further deflection does not occur and the end of the bone deforms against the end-plate of the appliance. Stipple represents cartilage. In the upper row, black indicates bone; in the lower, bone is represented by diagonal lines with the postimplantation bone formation by contradirection of lines. Force bearing on the bone is suggested by arrows. For simplicity, the lower row represents only the upper half of a bone and secondary centers are ignored.

parison of these with figures 7 and 8 shows that slightly more than 1 gm force develops during the predeformation period of up to 10 days. A force more than twice that magnitude (3.0 gm) is produced by the end of what we have called phase 2 (10 to 15 days). In phase 3 the force builds up to nearly 13 gm. The increments in length in table 2, by necessity of course, show the same pattern, and both match rather well the sequence of three phases suggested by morphogenesis. One may say that for this particular bone at these specific developmental levels, obvious deformations begin with between 1.2 and 3.0 gm longitudinal compressive force and that early cessation of longitudinal growth and some subsequent deformation of bone are associated with a prolonged force in excess of 12 gm.

Histological findings. We have previously documented the reaction of young long bones to subcutaneous implantation and the survival and continuation of essential cartilage maturation and osteogenesis (Felts, '57a, '57b, '59). In the present investigation, the deformity of the compressed humeri makes it virtually impos-

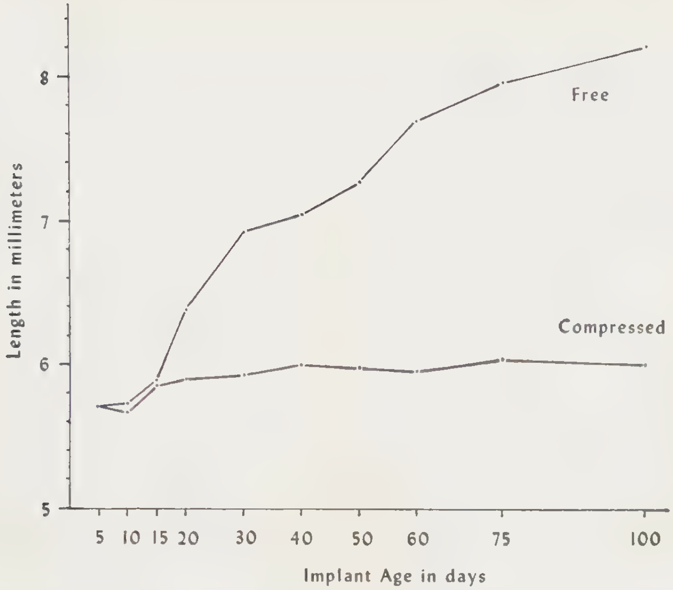


Fig. 8 Graphic representation of lengths of compressed and free implants against duration of implantation. Each point indicates the mean length of all implants collected for that interval. This graph should be compared with the three phases shown in figure 7 and is discussed in text.

TABLE 1

Mean deflections and approximate forces produced by experimental humeri

Days implanted	Mean deflection	Approximate force
	mm	*gm*
5	0.013	0.1
10	0.107	1.2
15	0.261	3.0
20	0.335	5.1
30	0.446	12.3
40	0.422	11.5
50	0.456	12.8
60	0.433	12.1
75	0.428	11.9
100	0.431	12.0
150	0.450	12.5

TABLE 2

Mean overall bone lengths

Days implanted	Unstressed implant	Experimental
	mm	*mm*
5	5.70	5.70
10	5.72	5.66
15	5.88	5.86
20	6.39	5.90
30	6.92	5.93
40	7.04	6.00
50	7.28	5.99
60	7.70	5.96
75	7.78	6.05
100	8.23	6.02

sible to orientate the humeri and cut in the planes that yield the single-section tissue maps required for this type of morphological paper. However, the most important observations from numerous section of free and compressed implants may be briefly summarized:

1. Unless otherwise indicated below, the appearance and distribution of cartilage, bones and the germinative tissues were the same in the two series, and as indicated in our earlier studies.

2. The proximal cartilage usually possesses a superficial central region of achromasis (interpretable as necrosis or at least nutritional insufficiency) which extends no further down than the level that will contain the secondary center; it is associated with the gap in the secondary center in the advanced specimens.

3. The early growth cartilage (or epiphyseal line or plate) is identical in depth and contour with that of the free implant, but as this growth zone comes to occupy levels further up in the deforming cartilage, it becomes more irregular in contour,

rather less in depth and—as would be assumed from the cleared specimens (figs. 4 and 5)—wider than in the free implants.

4. As first formed, the proximal secondary center is shaped like that in the free implant, but then becomes progressively flattened. As in most implants, the articular cartilage is often deficient and, eventually only the flattened center lies between the appliance plate and the comparatively thin growth cartilage.

5. The bony shaft of the compressed implant is rather thicker-walled than that of the free implant, but not remarkably so. The normal long bones of the mouse do not possess a complex of numerous trabeculae in the metaphyses and no significant increase in number, length or diameter of trabeculae was noted in any of the compressed humeri.

DISCUSSION AND CONCLUSIONS

This investigation has indicated the practicability of combining subcutaneously implanted long bones with simple mechanical appliances to test the relationship of determinable forces to growth processes. In retrospect, one might find several faults with experimental design and procedures, but in this initial approach to a virtually unexplored area, our basic aims were achieved.

Actually, in terms of the intent and results of this study, the appliance was nearly as efficacious as it was unsophisticated. It would be unnecessary to run additional series with varying thicknesses of wire unless one wished to study possible effects of the *rate* of loading upon implant growth. If the wire had been thicker, producing greater resistance to elongation, then the three phases probably would have transpired in proportionally shorter intervals of time—the opposite being true if the wire were thinner. One may at least theorize an appliance of this type in which the wire is so thin that the load limit of the cartilage is never reached and, conversely, one so thick that deflection does not take place. On the basis of our experience, one worthwhile modification in the appliance would be perforations in the end-plates to allow access of the vascular connective tissues to the central surfaces of the cartilages. This might have prevented the occurrence of bipartite secondary centers, but this condition does not seem to have altered the fundamental result of the experiment.

The present study was carried on with total organ involvement over a relatively long period of time, one encompassing virtually all of postnatal development. For this reason it is difficult if not unwise to draw direct comparisons with earlier (cited) studies on the effects of restrictive staples or springs on definitive epiphyseal plates only, in clinical patients or experimental animals. This desirable comparison is prohibited, not by the mere size of implant or nature of the appliance, but rather by the composition of the developing whole organ. Here we are dealing with a relatively soft cartilage mass which, in general, grows centrifugally while having a specific and related site of longitudinal growth in its base against the bony shaft. Further, this mass decreases continually in relative and absolute volume as it is replaced by bone, the presence and distribution of which the cartilage dictates. Theoretically at least, the *stress* evolved in such an experiment is calculable as force per unit cross-sectional area, but this is complicated here by the changing structural and growth characteristics of the subject. The only meaningful cross-section would be one through the longitudinal (cartilage) growth center, but it obviously undergoes a progressive areal increase and, further, analysis of this alone would ignore the deformation and diverted proliferation beyond it. It would be equally erroneous to consider simply the area of contact of cartilage and metal plate and, of course, the relation of force to cross-sectional area of the bony shaft is not pertinent to the process of elongation. Calculation of stress, therefore, is not practical. It is clear, too, that *strain*, as understood in studies of postmortem stress/strain relationships (Evans, '57) (unit linear alteration per unit stress), is virtually meaningless. While one may readily visualize gross deformation in the compressed cartilage mass, it is quite another problem to distinguish between the true distortion (strain) and diverted proliferation components in such a deforming mass.

The most meaningful comparison of our results is that with the forces normally encountered by the mouse humerus. We have not been able to ascertain the proportion of total body weight carried by the individual forelimb of the mouse, not to mention the muscular forces acting across the shoulder and elbow. However, it is possible to determine the quarter-weight of the mouse from the average weight of samples of mice in our colony. Such division of animal weight by the number of extremities produces a static value not taking into consideration the alternating increases and decreases in force with walking, running and jumping. However, this would seem to approximate a satisfactory working figure, perhaps rather high because of the apparently larger share of body weight carried by the hindlimbs. A reasonable sample of growing mice yields quarter-weights of approximately 1.3 gm at 12 days, 2.3 gm at 17 days, 4.0 gm at 32 days, and 6.2 gm at 100 days. The first three correspond to implant intervals of 10, 15 and 30 days plus age of two days at implantation; the last approximates the end of growth and development. By reference to the force values in table 1, it can be seen that quarter-weight is equal to or just exceeds the experimental force at 10 days (at which time free and compressed implants are essentially identical), but that the compressive force exceeds (by 21%) the quarter-weight at 15 days (by which time the implant has deflected the appliance nearly as much as it ever will). At the later ages, the experimental force far exceeds quarter-weight, by 3× at 30 days and 2× at 100 days. The decrease during the last age interval is obviously due to the great increase in weight in the adult mouse. On this basis, the implanted humerus is seen to exceed normal weight load levels early in the period of rapid deflection of the appliance, doing so with incipient but progressive deformation of cartilage, but without drastic retardation of longitudinal growth. Further elongation, however, evolves forces sufficient to grossly deform cartliage, but forces still further beyond normal weight-bearing are required to suppress growth and result in early epiphyseal closure. It is significant, however, that the forces thus produced are not sufficient to cause major deformation of the bony shaft. It may be concluded, therefore, that the growing long bone of the young mouse possesses a combination of biophysical characteristics capable of sustaining configuration and growth behavior in the presence of longitudinal compressive force well beyond those encountered in the normal function of the limb.

It would be facile but dangerous to follow the above with the unqualified statement that the developing long bone is possessed of a specific "physiological limit" which, like the safety limit of a properly man-made structure or vehicle, is set high. If one were dealing with an experiment in which the single epiphyseal plate had been compressed without involvement of the diaphysis and epiphysis, such semantics might be permitted. However, if one wished to use some such term in reference to the present results, then it would need to be recognized that the limit of the cartilage mass as a precisely shaped articular unit would be at one force level, its limit as an ossification format at a second level, and its limit as a site of at least minimum longitudinal growth at still another. Clearly, the radiologist, anthropometrist and anatomical dissector would display varying levels of appreciation of our results had it been possible to carry out this experiment *in situ* in the growing organism.

While there are certain points of comparison between this investigation and those of Glucksmann ('38, '39, '42), there are very significant distinctions and contrasts in technique and the nature of the experimental subject. Glucksmann worked with preosseous cartilage models and very early ossification stages of chick bones *in vitro,* placing them between explanted rib segments which were drawn together by degeneration of intercostal muscle fibers ('38) and in positions where one bone impinged on another as growth occurred in multiple cultures ('39, '42). In early preosseous subjects he was able to demonstrate compression distortion that was reflected in subsequent ossification; in more advanced explants, there was greater resistance to compressive force and subsequent bone was orientated against the direction of force. He found too, that force evolved in elongation of a cartilage model against another was sufficient to result in gross bending of the model in its middle region—with deformation inversely proportional to age and degree of ossification. These were his essential morphogenetic findings, and his elegant nonquantitative approach to biomechanics *in vitro* substantiates the incidental observations of Murray ('36) and Fell ('56) that elongating embryonic skeletal organs may be deformed by resistance of respectively, chorioallantoic tissues and *in vitro* plasma clots. However, it is clear that the early embryonic explant and graft, when but a rapidly growing mass of cartilage surrounded in its central region by, at most, only a monolamellar bony sheath, cannot be thought of as merely a smaller version of the organ with which we have dealt in this study; similarly, the humerus we have used was not simply a minature juvenile or young adult bone in its behavior.

One of our expectations at the initiation of this study was that the shafts of the compressed humeri might be of greater midsection diameter than those of the free implants. The relation of bone thickness to activity and load bearing is, of course, virtually a classic concept (e.g., Wermel, '35). However, this was not our finding, for there was but irregular occurrence of thicker shafts, and—more surprising—the advanced compression series displayed the same absolute and relative reduction in central diameter that has been seen here and previously in free implants. In relation to this, it has been ". . . theorized that after completion of growth, skeletal form is maintained in balance with postural and muscular forces, and that absence of these forces in the case of the implant removes the causative factor in form maintenance." (Felts, '59, p. 212). Although longitudinal compression, in spite of the cartilage "shock absorber," might be considered *a priori* a functional substitute for some of the normal forces acting on the bone shaft, it evidently was not. Whether the lack of response was due to absence of the correct magnitude and direction of force, or to a need for some degree of intermittency of force, or a combination of these and other factors will not be ventured without further investigation.

There are clearly many other problems in skeletal organogenesis which may be approached with this or similar techniques for application of measurable or known forces to isolated skeletal parts. In regard to long bones, the present appliance can be used in testing the response of immature implants to compression when in rachitic hosts and, with modifications, it can be applied to the study of the behavior of younger, fully cartilagenous organs. Wire, in other configurations, may supply tension to developing skeletal parts. Another problem suited to either the resilient wire appliance or one in the form of a static clamp (e.g., a cast plastic "C") is the response of the developing centra and discs of the vertebral column to compression. To one degree or another, these are the subjects of current investigation in this laboratory.

LITERATURE CITED

Barnicot, N. A. 1941 Studies on the factors involved in bone absorption. I. The effect of subcutaneous transplantation of the bones of the Grey-lethal House Mouse into normal hosts and of bones into Grey-lethal hosts. Am. J. Anat., *68:* 497–531.

Blount, W. P., and G. R. Clarke 1949 Control of growth by epiphyseal stapling. J. Bone Joint Surg., *31A:* 464–477.

Crelin, E. S. 1954 The effects of androgen, estrogen and relaxin on intact and transplanted pelves in mice. Am. J. Anat., *95:* 47–73.

Evans, F. G. 1957 Stress and Strain in Bones. Charles C Thomas, Springfield.

Fell, H. B. 1956 Skeletal development in tissue culture. In: The Biochemistry and Physiology of Bone. Academic Press, Inc., New York.

Felts, W. J. L. 1957a Tissue survival in mouse whole bone transplants. Transpl. Bull., *4:* 5–10.

——— 1957b A comparison of subcutaneous implants of isologous and homologous immature whole mouse bones. Ibid., *4:* 131–135.

——— 1959 Transplantation studies of factors in skeletal organogenesis. I. The subcutaneously implanted immature long-bone of the rat and mouse. Am. J. Phys. Anthrop., n.s., *17:* 201–215.

Gelbke, H. The influence of pressure and tension on growing bone in experiments with animals. J. Bone Joint Surg., *33A:* 947–953.

Gillette, R., D. Mardfin and I. Schour 1957 Osteogenesis in subcutaneous rib transplants between normal and ia rats. Am. J. Anat., *99:* 447–472.

Glucksmann, A. 1938 Studies on bone mechanics *in vitro*. I. Influence of pressure on orientation of structure. Anat. Rec., *72:* 97–115.

——— 1939 Studies on bone mechanics *in vitro*. II. The role of tension and pressure in chondrogenesis. Ibid., *73:* 39–55.

——— 1942 The role of mechanical stresses in bone formation *in vitro*. J. Anat., *76:* 231–239.

Haas, S. L. 1945 Retardation of bone growth by a wire loop. J. Bone Joint Surg., *27:* 25–33.

Murray, P. D. F. 1936 Bones. A Study of the Development and Structure of the Vertebrate Skeleton. Cambridge University Press, Cambridge.

Siffert, R. S. 1956 The effect of staples and longitudinal wires on epiphyseal growth. J. Bone Joint Surg., *38A:* 1077–1087.

Strobino, L. J., G. French and P. C. Colonna 1952 The effects of increasing tensions on the growth of epiphyseal bone. Surg. Gyn. Obst., *95:* 694–700.

Wermel, J. 1935 Untersuchungen über die Kinetogenes und ihre Bedeutung in der onto- und phylogenetischen Entwicklung (Experimente und Vergleichungen an Wirbeltierextremitäten). 2. Veränderungen der Dicke und der Masse der Knochen. Morph. Jahrb., *75:* 92–127.

Willis, R. A. 1936 The growth of embryo bones transplanted whole in the rat's brain. Proc. Roy. Soc. Lond. (B), *120:* 496–498.

The Effect of Polygamy and Infanticide on the Sex Ratio

RICHARD F. SHAW
University of Virginia School of Medicine, Charlottesville, Virginia

Darwin (1871) in *The Descent of Man* speculates on how the sex ratio might be adjusted by natural selection. After considerable discussion and some ingenious remarks he concludes that the whole subject might better be left for later times. Not until 1930 was something approaching a solution offered by Fisher. He considers a species in which parents care for the young and indicates that under such circumstances the primary sex ratio might be adjusted to a value other than one-half. This point has not been widely quoted presumably because Fisher's argument, although non-mathematical is nevertheless difficult to follow. His views become clearer when the sex ratio in the *absence* of parental care is understood. This aspect of the problem is very important in itself since most animals do not care for their young.

The basic principle can be readily seen from a simple example. Imagine a population of two males, ♂$_0$ and ♂$_1$, together with an unspecified number of females. Although both produce two offspring, ♂$_0$ produces one son and one daughter while ♂$_1$ produces two sons. So long as each produces the same number of offspring we would say that one is as fit as the other; that if the sex ratio is heritable, still no selection is taking place.

This cogent reasoning is wrong, as becomes clear when we consider the grandchildren of these males as shown in figure 1. If the one female produced, mates at random with the three males of her generation the three kinds of offspring 1, 2, and 3 will be produced in equal frequency. The autosomal genes of these offspring have the following origin. Fifty per cent of the genes in individual 1 are from ♂$_0$, the other 50% coming from the two grandmothers which are not shown in the diagram. In both individuals 2 and 3 the genes are one-fourth from ♂$_0$ and one-fourth from ♂$_1$. This is summarized in table 1. The total effect is that, of all the genes in the generation of the grandchildren, two-sixths come from ♂$_0$ and one-sixth from ♂$_1$.

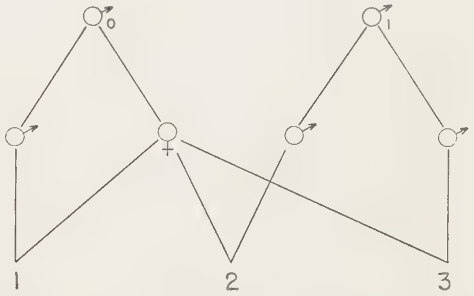


Fig. 1 The descendants of two males producing different sex ratios.

This means that, under the circumstances of the example, there is a strong selection pressure, and it is important to know whether this selection pressure is directed against the primary sex ratio or the ratio at adulthood. This is readily answered from figure 2. That example is similar to the one just given, except for the assumption here that half the sons die while all the daughters live. The outcome is the same as before, with ♂$_1$ contributing one-sixth and ♂$_0$ two-sixths.

Clearly the selection pressure is determined only by the primary sex ratio. If selection stabilizes the sex ratio at an equilibrium point—a matter to be con-

TABLE 1

Genetic contributions of the males in figure 1

Fraction of genes from	To individuals			To whole generation
	1	2	3	
♂$_0$	½	¼	¼	2/6
♂$_1$	0	¼	¼	1/6

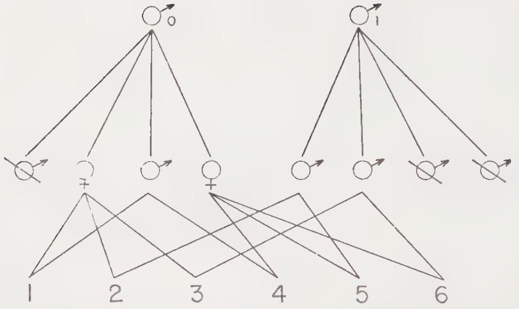


Fig. 2 The descendants of two males producing different ratios where male zygotes have a 50% chance of dying.

sidered shortly—then it is the primary sex ratio which is so stabilized.

The strong selection for sex ratio shown by figure 1 is a general phenomenon and is not due, as might be supposed, to there being only two males or to any other peculiarity of the illustrative example. It has been shown (Shaw and Mohler, '53) that the expected contribution of a male to the generation of his grandchildren is proportional to

$$\frac{m}{M} + \frac{f}{F}$$

where m is the sex ratio of the progeny of the male under consideration and M that of the population into which they are born, f and F representing the corresponding proportion of the females. This formula applies to a population of any size and we may, if we like, take the symbols $♂_0$ and $♂_1$ to mean not the two specific males of figure 1, but two *kinds* of male present in the same population and differing in their sex ratio. As a measure of fitness of $♂_1$, taking $♂_0$ as a standard of comparison we can write

$$w = \frac{\frac{m_1}{M} + \frac{f_1}{F}}{\frac{m_0}{M} + \frac{f_0}{F}} .$$

Supposing as before that m_0 is equal to ½ and simplifying we have

$$w = 2(m_1F + f_1M) \qquad (1)$$

As an illustration of what this expression means we may apply it to the example in figure 1. Here

$$w = 2\,[\,1(1/4) + 0(3/4)\,] = 1/2$$

This result, that $♂_1$ has a fitness of one half, corresponds to the previous finding that he contributes 1/6 of the genes as compared to 2/6 by $♂_0$.

We may now ask what, in a more general way, does the expression tell us? Specifically, under what circumstances will $♂_1$ be more fit than $♂_0$? Under what circumstances will they be equally fit? It can be said immediately that $♂_1$ can never be fitter than $♂_0$. This is because w has a maximum at 1, a fact which can be verified by the reader either by substituting numbers for M and m_1 in equation 1 and plotting curves or by equating the partial derivatives to zero. By either method one finds that a fitness of w = 1 occurs only if m_1 = ½ or if M = ½. It follows that when the sex ratio of $♂_0$ is ½ and that of $♂_1$ is any other value $♂_1$ will always be at a disadvantage. Only when its frequency in the population is zero can $♂_1$ be as fit as $♂_0$. From this it is clear that when the frequency of $♂_1$ is not near zero it will become so due to his low fitness.

The whole argument so far is in terms of *male* parents which produce differing sex ratios. Clearly, exactly the same reasoning could be applied to the females and the argument based upon genes which exert their effects in them. We could not, by the methods employed up to this point, consider the behavior of a gene which influences the sex ratio through parents of either sex. To understand what this means consider how a gene affecting the primary sex ratio may produce its effect. It must operate either by causing the male to produce X and Y sperm differing in their ability to fertilize, or it must operate by causing the female or her egg cells to discriminate against one or the other of

TABLE 2

Genetic contributions of males of figure 2

Fraction of genes from	To individuals						To whole generation
	1	2	3	4	5	6	
$♂_0$	½	¼	¼	½	¼	¼	2/6
$♂_1$	0	¼	¼	0	¼	¼	1/6

these kinds of sperm. We could hardly expect one and the same gene to produce both of these results. Thus if we want to consider the behavior of a single gene, it will surely act in parents of one sex only, and the scheme presented will be wholly adequate.

If, however, we want to consider more than one gene locus we must suppose that some could produce their effect in the male, and some in the female parents. If so, the simple diagrams and tables used at the beginning are no longer applicable. A different approach must be taken as follows:

If there are N zygotes in a generation and NM of them are males, then one male zygote is expected to contribute ½NM of the genes going to the next generation. Likewise a female zygote expects to contribute ½NF. The "contribution" may be said to be the genetic value of a male and of a female zygote respectively. Equilibrium must occur when the value of a male is equal to that of a female, otherwise parents which have a genetic tendency to produce the more valuable sex will be favored over the others. So it follows that the population stabilizes itself at $M = F$.

In all of the foregoing, certain assumptions have been made. The first is that only autosomal genes are present. This means that sex linked genes are supposed to be absent or of negligible importance. This is certainly not true for organisms such as Drosophila but is more nearly so for some mammals in which sex linked genes are a rarity.

It has also been assumed that the sex ratio is not correlated with family size or viability of the young. This latter assumption does not strictly hold for mammals as they gestate their young internally and care for them after birth. Consequently if sons die more readily than daughters a mother which produces mostly sons will lose many of her offspring. She will, at the death of each son, be freed from the burden of gestation, nursing, or other parental care and will be able to reproduce again sooner than otherwise. This will make for a correlation between sex ratio and number of offspring. This idea, which is due to Fisher ('30) has been expressed in more detailed mathematical terms by Crow (unpublished). The result is that selection leads to the production of zygotes of the less viable sex at a rate greater than 50%. Fisher's scheme probably holds for many mammals including man.

Two features of human populations besides parental care have sometimes been thought to affect the primary sex ratio. They are polygamy and infanticide. Whether polygamy may lead to an equilibrium primary sex ratio other than one-half can be determined from the example of figure 2. Although certain males in that example have been spoken of as dying, the logic of the discussion really depends not on their death, but on their failure to reproduce. Whether they die or are sterile or are prevented from mating by a polygamous social system, the outcome is the same. Under any of these conditions the population will reach equilibrium when the zygotes produced are half males and half females.

This clears up a puzzle which has troubled some biologists of my acquaintance and probably others besides. That is the question of why, in seals and other such polygamous animals, natural selection does not produce a sex ratio more in accord with the proportion of the sexes which finally mate. The difficulty arises from the vague expectation that selection should produce an obvious kind of harmony, and is dispelled by the consideration of precisely how natural selection operates on the sex ratio.

That female infanticide might alter the primary sex ratio was considered by Darwin. He quotes the following argument from Colonel Marshall, a writer on the Todas, a hill tribe of India.

"Let us for the purpose of illustration take three families as representing an average of the entire tribe; say that one mother gives birth to 6 daughters and no sons; a second mother has 6 sons only, while the third mother has three sons and three daughters. The first mother, following the tribal custom, destroys 4 daughters and preserves two. The second retains her 6 sons. The third kills two daughters and keeps one, as also her three sons. We have then from the three families, 9 sons and three daughters, with

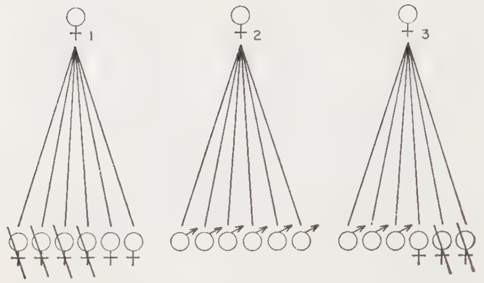


Fig. 3 The three females of Colonel Marshall's example and their offspring.

which to continue the breed. But while the males belong to the families in which the tendency to produce sons is great, the females are of those of a converse inclination. Thus the bias strengthens with each generation, until, as we find, families grow to have habitually more sons than daughters."

In this example there are too many grandchildren for us to conveniently draw a diagram of the kind used before. It is easy enough to begin the diagram, as shown in figure 3, by drawing the three females and their 18 offspring and then crossing out those which Marshall specifies as destroyed. It is not so easy to diagram all the kinds of matings which are possible among the survivors, but the outcome can be tabulated directly. Since there are two daughters of ♀$_1$ and 6 sons of ♀$_2$, there are 12 possible matings of these. Continuing in the same way we can get all of the possible matings. Probably the Todas did not practice brother-sister marriage, so let us exclude that possibility for the moment. Allowing random mating with this exception, the result can be expressed as a frequency table, table 3.

Assuming for the sake of concreteness that each kind of mating produces one offspring, the numbers in the cells of the table become the numbers of offsprin produced. The fraction of all genes i the final generation which come fro each of the three initial females ca now be found, just as was done in th earlier examples. For ♀$_1$ there are 12 + = 18 grandchildren out of a total of 2 individuals comprising the whole gener tion of grandchildren. Thus 18/24 or 3 of the individuals in the final generatio have ♀$_1$ as a grandparent. Each such ind vidual gets ¼ of his genes from ♀$_1$. Th means that (¼) (¾) = 3/16 of th genes in the final generation come fro ♀$_1$. By the same reasoning ♀$_2$ contri utes ¼ [(12 + 6)/24] = 3/16, and ♀ ¼ [(6 + 6)/24] = 2/16. Again these thre figures add up one-half corresponding t the fact that half the genes among th final generation come from the gran mothers, the other half being supplied b the grandfathers.

Inspection of these figures shows tw things of importance. First. the contrib tions of the three females are not all equa as anticipated, and thus some selectio pressure is at work. Second, the expect tion of Colonel Marshall is, neverthele not fulfilled; because, although the co tributions are not equal, they are balance The female-producer (♀$_1$) contributes e actly as much as the male-producer (♀$_2$ The fate of the population posed by Col nel Marshall is an equilibrium where fam lies with extreme sex ratios are present i the population, but in such proportion that the two extremes balance each othe and the primary sex ratio for the *whol* population is one-half.

From the earlier examples and discus sion the three females might have bee expected to have equal contributions. Th reason they do not lies in the prohibitio of brother-sister marriages. To permit thi requires us to put a 3 in the empty cell o

TABLE 3

Kinds of matings and the numbers in which they occur among the offspring of Col. Marshall's example

Females	Males	
	Six sons of ♀$_2$	Three sons of ♀$_3$
Two daughters of ♀$_1$	$2 \times 6 = 12$	$2 \times 3 = 6$
One daughter of ♀$_3$	$1 \times 6 = 6$	—

table 3. Calculated on this basis the contributions of the three females are then

$$\tfrac{1}{4}\left(\frac{12+6}{27}\right) = 18/108$$

$$\tfrac{1}{4}\left(\frac{12+6}{27}\right) = 18/108$$

$$\tfrac{1}{4}\left(\frac{6+3+3+6}{27}\right) = 18/108\ .$$

Whether incest prohibition really produces such strong selection for families of extreme sex ratio as it appears to in the very simple example is an interesting question which cannot be decided at the moment. The effect would appear to be small in large populations. What is clear is that whether brother-sister marriage is prohibited or allowed, the primary sex ratio of the population must stabilize at one-half.

A slightly different conclusion is reached if one considers the effect of parental care as is done by Fisher. This factor merits a separate treatment, and has been deliberately ignored here in order to concentrate on a more basic aspect of the sex ratio, one which must be understood before the effect of parental care can be profitably discussed.

SUMMARY AND CONCLUSION

The purpose of the foregoing has been to restate the principle that the primary sex ratio is subject to natural selection, putting the phenomenon more in biological than in mathematical terms; and to show specifically that neither polygamy nor infanticide can, by itself, have any effect on the primary sex ratio.

LITERATURE CITED

Crow, J. F. Unpublished.

Darwin, C. 1871 The Descent of Man. In combined edition of The Origin of Species and The Descent of Man. Modern Library, N. Y., pp. 608–611.

Fisher, R. A. 1930 The Genetical Theory of Natural Selection. Clarendon Press, Oxford.

Shaw, R. F., and J. D. Mohler 1953 The selective significance of the sex ratio. Am. Nat., 87: 337–342.

Book Reviews

THE FACE: IN FIVE DIMENSIONS. By Viken Sassouni. viii + 317 pp., Growth Center, Philadelphia, 1959.

This intriguingly titled loose-leaf publication follows the 1957 syllabus in roentgenographic cephalometry by Krogman and Sassouni. The 5 dimensions are the familiar three, plus those of growth and heredity. The book is for "communication and teaching purposes" and is "primarily directed to the student in maxillofacial orthopedia," reflecting the utility of roentgenographic cephalometry in diagnosis and evaluation in problems of malocclusion. The numerous illustrations "provide a source material which could be used for further clinical research."

Ten unequal parts compose the volume: Atlas, Analyses, Standards, Racial Comparison, Facial Typing, Facial Growth, Heredity, Pathology, Comparative Anatomy, and Orthodontic Treatment. Atlas gives a general orientation to dento-facial landmarks as seen in films, technique for making physioprints, cranio-facial muscle-bone relationships, and the integration of photographs, film tracings, and dental models. Analyses is a three-fold presentation of individual cases: comparison to averages on a standard deviation diagram, to a cephalometric standard, and analysis via the archeal technique of Sassouni. Standards presents composite tracings derived from normally occluded lateral and frontal head films of whites (4, 8, 12, 16 years and adult male); Negroes (6, 8, 12, 16 years and adult male); and Chinese (8 and 12 years). Racial Comparison summarizes the differences and similarities seen in superimposition of the composite standards at 8 and 12 years for white, Negro, and Chinese, and for white and Negro adult males. Facial Typing provides 31 cases illustrating normal occlusion, 11 cases with maxillary protrusion-mandibular retrusion, 10 cases with maxillary retrusion-mandibular protrusion, 21 cases with biprotrusion and open-bite, and 13 cases with biretrusion and deep-bite. Facial Growth uses the previous age-race composites to illustrate facial growth. Sassouni shows relative facial growth for the white series by taking all lateral composite tracings of the white series and superimposing them on the supraorbital plane and registering first on the anterior contour of sella turcica and anterior clinoid and, secondly, registering on "center 0" (the general region of convergence of supraorbital, palatal, occlusal, and mandibular planes as seen in lateral films). The adult male Negro and the 6-year Negro composites are superimposed in order to show facial growth. The Heredity part presents film tracings of two father-mother-child and one mother-child series. Part VIII, Pathology, contains lateral and frontal tracings of two cases of Cooley's Anemia and lateral tracings of one case of hypopituitarism, one treated and two untreated cretins, one acromegalic, and one cleft palate case. In Part IX, Comparative Anatomy, lateral and frontal film tracings are given of one adult male chimpanzee, one adult orang-utan, and one gorilla. Orthodontic Treatment is a brief review of orthodontic therapies and 5 case presentations of diagnosis and treatment.

From the anthropological viewpoint, the age-race standards (composites) and the race comparisons using the composites are particularly interesting. These are extremely important in concept but care must be taken in their use. The standards are composites of, generally, 16 males and 16 females of the "same" age. Aside from the basic confounding of male and female data, what "age" are we to use? Chronological age? Skeletal age? If we consider the remarkable discrepancies in male and female maturation rates, this question is of considerable importance in establishing any standard. "Which age?" is not resolved. And one may ask in racial terms what "white," "Chinese," and particularly "Negro" mean. These small cross-sectional samples are derived from large, heterogenous groups; whether or not the age composites within a racial series are comparable is debatable. Standards must be defined in strict terms. As Sassouni writes, "the addition of Negro and Chinese composites will permit a preliminary step in the problem of *racial* factors in malocclusion." We would extend the field of interest to racial factors in the total craniofacial complex and commend the present preliminary step.

While Sassouni's "archeal concept," which pervades the book, is primarily of interest to orthodontists, some comment upon it is in order. Sassouni sees normal dento-facial growth as a complex which can be described by a series of 4 concentric arcs on lateral head films. The anterior arc has for its center the convergent point of the supraorbital, palatal, occlusal, and mandibular planes; its radius is the distance from the convergent point (center 0) to nasion. From nasion, in the normal dento-facial complex, the anterior arc will touch the anterior nasal spine, the tip of the upper incisor, and pogonion. A second arc is drawn from subspinale downward. This, the basal arc, should pass through supramentale. A midfacial arc from temporale should be tangent to the anterior border of the maxillary first molar. The posterior arc from dorsum sella should pass through gonion. The normal dento-facial complex can then be related to these 4 arcs and deviations from the normal can be noted in individual films; these deviations become the basis for diagnosis and treatment in occlusal problems.

By registering on the anterior curvature of sella turcica and anterior clinoid (superimposing composites on the supraorbital plane), Sassouni identifies two trends: (1) the convergent center of the 4 planes moves, during maturation, from within the cranium, posteriorly and downward to a position external to the cranium, and (2) the relatively convex profile of the 4-year-old child becomes more "upright" or less convex with maturity. Such conclusions, however, are directly related to the particular registration used.

Now, whether or not these geometric abstractions have any real meaning or value can only be determined by clinicians I wish to take particular exception, there fore, to the use of the word "explains" i the following quotes: "In summary, th archeal analysis explains and describes th concomitant changes in size, proportion and position of the facial components dur ing their growth," and "During growth th face preserves its archeal balance. Th different archeal constructions are no identical; they vary. Their unfolding explains from a new point of view, in a synthetic way, the unfolding of the face." Th "archeal concept" is a way of looking at not an explanation for, phenomena.

Can the use of standards and geometri abstractions have predictive value in individual cases? "When average tendencie are considered there is a pattern type o growth, a certain parallelism, a certain constancy of proportions. When individua cases are considered this concept is difficult to apply. Changes in proportion tak place, all of which are not predictable on the basis of the first record (film)." Sassouni adds, "In other words, with our present knowledge, it is almost impossible t predict the amount and direction of growth on the basis of the initial facial types."

What of the predictive value of studying parental films in order to approximate the mature dento-facial complex in the offspring? This may permit an estimation o the location of "center 0" at maturity. I nasion and the other necessary points can be approximated in the same manner, the arcs to be expected in the child's adul face can be theorized and therapy applied "This is as yet tentative(sic)," writes Sassouni. The complex interplay of heredity and environment in the cranio-dento-facia complex is, at best, poorly understood.

The book contains an unpardonable number of spelling and grammatical errors References are made to more than 30 investigators and their work, very few of whom are cited in the bibliography. The bibliography, in point of fact, is composed of references for the most part not cited in the text. To one not familiar with these men and their work, this is gross negligence and does not permit a satisfactory evaluation of the present volume. If the book must stand on its own merit, it is quite obscure and open to major criticisms. If it is to be considered as Sassouni conceived it, "directed to the student in maxillo-facial orthopedia," and as source material for further clinical research, it no doubt is much more adequate. This, however, I am not competent to judge.

DONALD H. MORRIS
Department of Sociology and Anthropology
Arizona State University

RADIATION, GENES, AND MAN. By Bruce Wallace and Th. Dobzhansky. xii + 205 pp. $3.50. Henry Holt and Company, New York, 1959.

This is the best general book now available to the non-specialist in radiation genetics on the hereditary effects of increased exposure to ionizing radiation in human populations.

The opening 5 chapters give background information on genes and chromosomes, the regularities of reproduction and transmission of the genetic material, the nature of ionizing radiation, and the mutagenic effects of such radiation. Chapters 6 and 7 deal with the genetic structure of breeding populations and the distribution of mutant genes in such Mendelian populations. Mutational damage is measured in terms of Mullerian "genetic deaths"— a measure first proposed, as Muller has been careful to acknowledge, by the anatomist-anthropologist C. H. Danforth in 1921.

Chapter 8 is the core of the book and gives the message which moved the authors to write it. All radiation geneticists agree mutation rates go up with increased exposure to ionizing radiation. Wallace and Dobzhansky hold we do not know how to estimate the overall biological damage in terms of "genetic deaths" because we do not know how to give good values to the required selection coefficients. Under the *classical hypothesis* on the genetic structure of populations (given a constant environment) most mutant genes are considered deleterious in homozygotes and either neutral or somewhat deleterious in heterozygotes. Under the *balanced hypothesis,* which Wallace and Dobzhansky support, many or most mutant genes are considered both potentially heterotic (advantageous) when in heterozygotes and potentially deleterious when in homozygotes. The balance hypothesis holds mutation is ". . . not only the price for evolutionary plasticity; it is also the tax levied in order to preserve the status quo (p. 165)."

Everyone agrees that some loci in human populations consist of several mutually heterotic alleles, e.g., the hemoglobin S locus, and probably several loci for the antigens on red blood cells. Everyone agrees that genes at some loci identified by mutants with major effects seem to lack heterotic effects, e.g., hemophilia and galactosemia. Everyone would agree with Wallace and Dobzhansky that one difficulty in forecasting the risk to man from increased radiation is the uncertainty as to the proportion of loci that are "classical" and that are "heterotic." Everyone would agree this is not the only major problem.

The issue as to whether the "classical" or the "heterotic" hypotheses is more correct for human populations cannot be solved conclusively with the data now available. As Wallace and Dobzhansky say: "Probably the most important fact concerning the issue is that the data, evidence, and information on which, and only on which, conclusions should rest are as yet wholly inadequate (p. viii)."

Perhaps the chief quarrel geneticists who specialize on man would have with the book is that it omits too much of what is now known about radiation genetics in human populations. Studies of inbred human populations provide direct estimates of the mutational load in man. These studies give information superior to indirect results obtained from *Drosophila* investigations (see p. 118). Large-scale studies now in progress (based on the populations of Hiroshima, Nagasaki, and Shizuoka) should provide reliable information which will permit making better estimates of the genetic hazards of the atomic age. The final chapter, 9, is an argument in support of getting the type of knowledge we need to assay the combined effects of radiation, genes, and man.

Physical anthropologists who wish to understand the technical problems in contemporary attempts to comprehend the radiation genetics of human populations will find this book an excellent introduction.

J. N. Spuhler
Departments of Anthropology
and of Human Genetics
University of Michigan

AN ODONTOMETRICAL STUDY ON THE NORWEGIAN LAPPS. By Reider Selmer-Olsen. 171 pp, 35 figures, 47 tables and 2 plates. Skrifter Utgitt Av Det Norske Videnskaps-Akademi 1 Oslo. 1 Mat.-Naturv. Klasse 1949. No. 3.

Selmer-Olsen has presented a most comprehensive odontometrical study which not only includes materials on the Norwegian Lapps but also by the inclusion of comparative materials has presented an excellent source book for statistical data on a good many other populations.

The author is quick to point out that the size of teeth alone has a limited value as a racial characteristic because of the high variability within the different collections. For this reason in his summation he states that large series are therefore required in such studies and determinations.

One of the most important contributions in this publication is the review of the literature on odontometry and the discussion and definition of nomenclature and measuring techniques. There is only one disturbing point and that is Selmer-Olsen's decision to follow Martin's lead in using the term "crown breadth" for the mesiodistal dimension and "crown thickness" for the labiolingual. However, in the tables themselves and in the text he avoids complications by designating the diameters as mesiodistal or labiolingual as the case might be.

The investigation and study covers the roots as well as the crowns. The author states though, that owing to the large variation in the roots they are of less significance than crowns in racial comparisons.

The Lapp dentition is characterized by Selmer-Olsen as having small tooth crowns rather large and long roots with pointed apices, crown size decreasing greatly from the first to third molar, and a relatively thicker character to the teeth generally. Only the Bushman and Hungarian dentitions show as small averages in crown size as do the Lapps.

Various indices of tooth measurements are compared in the study between racial and local groups. The variation coefficients of most of the measurements ranged in the vicinity of 8.0, with the females showing a slightly larger figure. From the tables it is seen that some of the lowest values for the individual coefficients, both in the male and female all lie either in or above the group considered moderately high variation and none in the moderate low category, that is, below 4.5.

This work is certainly one of the most thorough-going analyses of odontometry and should be consulted in any problem of this type. It would be of great value to have a thorough-going morphological study of this population to parallel the fine work done in the metrical areas.

Albert A. Dahlberg
University of Chicago

THE ANTECEDENTS OF MAN. By W. E. Le Gros Clark. 374 pp. $6.00. Quadrangle Books, Chicago, 1960.

This is a fascinating book which deals with the evolution of man's close relatives, the non-human Primates. Le Gros Clark, one of the world's authorities on Primate evolution, presents this difficult subject in a straight forward manner intelligible to both the interested layman and the serious student. This introductory book presents not only the author's latest thinking, but also the basic principles which he has used in arriving at his conclusions. Although it treats the same subject matter as his earlier book, The Early Forerunners of Man, this is not just a second edition.

The book's 374 pages, including index, are divided into 10 chapters. The first two serve as an introduction by reviewing certain principles which must be observed when the data of comparative anatomy and paleontology are interpreted from the phylogenetic view point. There is included a short classification and a brief review of the living and fossil forms. These chapters serve to define the area to be considered, to indicate the type of evidence to be used, and to outline some pitfalls which must be avoided.

The factual evidence of the course of Primate Evolution is presented in 7 chapters which deal in turn with dentition, skull, limbs, brain, special senses, digestive system, and reproductive system. Those familiar with the author's repeated emphasis on the total morphological pattern may find this systemic approach somewhat strange. The author justifies his procedure by pointing out that this is ". . . a necessary preliminary to the formulation and solution of scientific problems in general. But it is a procedure which always needs to be followed by an attempt at resynthesis."

The resynthesis is to be found in the final chapter: a chapter which could only be written by someone thoroughly familiar with his subject. It should be read by everyone interested in Primate evolution.

There are certain features of the book which are worth noting. (1) The author deals strictly with the course and not with the causal agents in Primate evolution. (2) For those not familiar with the intricacies of Primate nomenclature (and how many are?) the brief classification given will hardly be adequate for keeping the various forms straight. (3) This is not strictly a book on Paleontology. Clark uses all the morphological data which he considers appropriate. (4) There is no use made of behavioral or ecological data. Both of these fields are assuming importance in the understanding of evolution. In view of the size of the book and its stated problem, this is not a serious criticism. (5) There is one almost unique feature of the book: namely, a specific statement of the principles which are used for the interpretation of data. All too often, authors in this field consider it unnecessary to state the logical bases for their argument. Clark not only states his but also uses them consistently.

JAMES A. GAVAN
Medical College of South Carolina
Charleston, South Carolina

Proceedings of the Twenty-Ninth Annual Meeting of The American Association of Physical Anthropologists[1]

The Association met in Washington, D. C., Thursday through Saturday, May 12–14, 1960, by invitation of the Department of Anatomy of the Howard University College of Medicine. Registration totalled 118, and included representatives from 27 states and 8 foreign countries.

The meeting opened on a formal note with the presentation to President Greulich of the Key to the City by the Hon. David B. Karrick[2] of the Board of Commissioners of the District of Columbia. There followed seven scientific sessions, two of which ran concurrently on Friday morning. Included in these sessions were two symposia, one on Thursday afternoon, organized by John Buettner-Janusch, on "Evolutionary and experimental biology of the primates," and the other on Friday afternoon, organized by Gabriel W. Lasker, on "The teaching of physical anthropology." Thursday evening a Smoker was held in the Hotel Roosevelt by courtesy of the Wenner-Gren Foundation for Anthropological Research. The showing of anthropological films was a feature of the evening. At the annual dinner on Friday evening, held in Baldwin Hall, greetings were extended by Dr. Mordecai W. Johnson, Howard President, and Dr. Robert S. Jason, Dean of the College of Medicine. The Hon. Arthur S. Flemming, Secretary of Health, Education and Welfare, delivered the principal address, on "Meeting the needs of the aging."

The Executive Committee held its regular annual meeting the evening of May 11, 1960.

BUSINESS MEETING
May 12, 1960

The Secretary-Treasurer, Edward E. Hunt, had no reports ready for presentation, so no action could be taken along this line (see addendum, p. 92). President Greulich thereupon announced Dr. Hunt's resignation and the selection by the Executive Committee of T. D. Stewart to fill out Dr. Hunt's term of office.

The following new members, having been approved by the Executive Committee on May 11, 1960, were elected to membership by unanimous vote:

David Allbrook
Jack C. Bresler
Irven DeVore
Phyllis Eveleth
John Frisch
Carl Hammerstrom
Frank Johnston
Odorico Machado de Souza
Laura Newell
Miroslav Prokopec
Alphonse Riesenfeld
Elwyn L. Simons
Clyde C. Snow
Steven Vandenberg
Carol Welt

Two charter members were lost by death during the year: Bruno Oetteking and Harry H. Shapiro, both of New York City.

President Greulich thanked the Association for the honor it had bestowed upon him earlier in the year when it had nominated him for the Viking Fund Award. He reported that he had been presented for the medal by the Vice-President, J. Lawrence Angel, at the annual dinner of the Wenner-Gren Foundation in New York on March 4, 1960.[3]

The Editor's Report, as given by William S. Laughlin, was optimistic about the Journal reaching an up-to-date publication schedule during 1960. He pointed out that the two-column format had been used successfully throughout volume 17 for 1959, and that manuscripts were coming in at a satisfactory rate.

T. D. Stewart called for a vote of censure against James N. Spuhler, the Secretary-Treasurer preceding Edward E. Hunt, for his failure to seek help when he had difficulty in completing the affairs of his office and when this resulted in an overly long delay in transferring funds and records to the new Secretary-Treasurer.

---

[1] Prepared by T. D. Stewart.

[2] Died August 6, 1960.

[3] See this Journal, n.s. vol. 18, no. 3, September 1960, pp. 231–234.

After considerable discussion the motion was tabled.

J. Lawrence Angel offered a resolution on racial equality. After much discussion and several attempts to rewrite the resolution it was voted down principally on the grounds that the Association was already adequately on record in this matter.[4]

The Resolutions Committee, consisting of Stanley M. Garn and A. J. Kelso, submitted the following report which was unanimously accepted:

> Be it resolved that this Association expresses its pleasure and gratitude to our hosts, Howard University, its president, Dr. Mordecai W. Johnson, Dr. Robert S. Jason, Dean of the College of Medicine, and our long-time colleague and past president, W. Montague Cobb, for their kindness and solicitude, for our physical comfort and nutritional welfare, and environmental protection in general.
>
> Be it further resolved that our appreciation be extended to the Program Committee, T. Dale Stewart and Marshall T. Newman, for their skillful management and introduction of parallel sessions in the face of the growing complexity of our meetings.
>
> Be it further resolved that we are honored with the presence of Dr. David B. Karrick, member of the Board of Commissioners, District of Columbia, and fellow anthropologist, and Dr. Arthur S. Flemming, The Honorable Secretary of Health, Education and Welfare, at this our 29th annual meeting.
>
> And be it resolved that we again express our indebtedness to Dr. Paul Fejos and the Wenner-Gren Foundation for the support and encouragement of physical anthropology, including its social aspects.

The Nominating Committee appointed at the preceding meeting announced the following candidates for office, whose election immediately followed the closing of nominations: Vice-President, Gabriel W. Lasker, to serve for two years; Executive Committee member, Marcus Goldstein, to serve for three years.[5]

The business meeting adjourned about 5:30 P.M.

ADDENDUM

On February 24, 1961, Dr. Hunt submitted his Treasurer's Report for the period from April 1, 1959, to May 14, 1960, together with the Association's financial records for the period of his service. Unfortunately, the bank balances which he cited for the beginning and ending dates do not agree with those contained in the statements issued by the Harvard Trust Company. Since adjustments involve the statement supplied by Dr. Hunt in April of 1959 (see this Journal, n.s. vol. 18, no. 4, p. 353–365), it is necessary to combine and adjust the two reports. This action does not imply dishonesty on the part of Dr. Hunt, but only the need for an accurate accounting as a basis for the next Treasurer's Report.

---

[4] See this Journal, n.s. vol. 13, no. 2, 1955, pp. 376-377; n.s. vol. 14, no. 2, 1956, pp. 365-367.

[5] Clark Howell who was serving out Dr. Greulich's term on the Executive Committee will now fill out Dr. Lasker's term.

REPORT OF THE TREASURER

October 24, 1958—May 12, 1960

Deposits representing transfer of Association funds from J. N. Spuhler:

October 24, 1958 (check dated October 20, 1958)		$4000.00
November 10, 1958 (check dated July 8, 1958)		100.00
December 10, 1958 (check dated December 3, 1958)		453.93
April 11, 1960 (check dated December 8, 1959)		65.77
		$4619.70

Additional deposits by years:

1958:	Dues	$ 30.00	
1959:	Donation for prize at 1959 meeting	100.00	
	Dues	1282.50	
	Refund from Wistar Institute	97.39	
	Unspent portion of check no. 5	32.78	
1960:	Dues	151.00	1693.67
			$6313.37

Withdrawals by years:

1958:	For stamps	$ 10.00	
	For stationery	70.56	
	For printing checks	3.74	
	Check returned by bank	10.00	
1959:	To Wistar Institute (extra printing costs of article in Journal)	117.39	
	To Wistar Institute (subscriptions to Journal)	245.33	
	For rubber stamps	5.17	
	For train fare	40.90	
	For stationery and cash	133.37	
	For expense of 1958 meeting	24.54	
	For printing and mailing program for 1959 meeting	178.84	
	Checks returned by bank	30.00	
1960:	For typewriter for editor of Journal	259.28	
	UNESCO coupons returned by bank	8.00	1137.12
	Bank balance, May 12, 1960		$5176.25

SCIENTIFIC PAPERS

1. *Dental morphology of the early inhabitants of Kish, Mesopotamia, 3000 B.C.* Virginia M. Carbonell, W. G. Zoller Dental Clinic, University of Chicago.

The dentition of the early inhabitants of Kish, Mesopotamia, 3000 B.C., was studied in order to determine dental traits common to the group and evaluate the evolutionary position of their dental development.

Detailed examination of tooth morphology was accomplished by observation of dental traits such as cusps, grooves, shape and size of teeth. The data collected were submitted to statistical analysis.

Dental traits such as dental tubercles, Carabelli's cusp, reduced number of cusps and size of teeth manifested advanced evolutionary trends of the human dentition. Reduction of the metacone or disto-buccal cusp of the maxillary molars was observed in the group. Attrition or wear on the occlusal surfaces of the teeth suggested the nature of the diet of the inhabitants.

2. *Crown characters of the deciduous dentition of Japanese-American hybrids.* Kazuro Hanihara, Department of Legal Medicine, Sapporo Medical College and University of Chicago.

Since 1949 members of the Department of Anthropology, University of Tokyo, under the direction of Dr. Suda, have been studying the physical traits of hybrids born of Japanese mothers and American fathers. The speaker's concern has been particularly with the morphology of the deciduous dentition of these hybrids. Since reports on the human primary dentition are rare and there is difficulty in finding comparative data, the speaker has taken the opportunity while in the United States to study a number of deciduous dentitions of Whites. Thus he now has control data on Japanese and white children. At this time the three groups—Japanese, Japanese-American white hybrids, and American Whites—will be compared mainly as regards their crown measurements and some of their morphological traits.

As a whole, there seems to be a tendency for the Japanese-white hybrid group to take an intermediate position between the Japanese and white children in most of the crown measurements as well as in the frequencies of several crown characters, such as crown pattern, Carabelli's cusp, protostylid and so forth.

For further comparison, data on Japanese-American Negro hybrids will be shown. The findings here can only be characterized at present as suggestive, because observations have not yet been made by the speaker on American Negro children.

3. *Civilization, diet, mouth form, and dental health.* J. Lawrence Angel, The Jefferson Medical College, Philadelphia.

By age 40 two-thirds of our teeth are diseased whereas primitive peoples have less than one-third diseased. Hominid enamel and dentin are liable to poor calcification both genetically and from malnutrition. "Civilized" fermentable foods breed mouth bacteria whereas "primitive" rough diets wear teeth (0.1–0.2 mm annually) to edge bites, promote mobility, secondary dentin, and good blood supply. How do diet and mouth function interact?

As a "natural" experiment 1,000 mouths from Greece show dental lesions (adjusted to age 41) steady at 25–27% during prehistoric times except for Mycenaean kings at 7%! With Classical civilization lesions decrease to 16%, rise to 25% in Hellenistic-Roman times, to 35% during Medieval-Turkish decline, and suddenly to 50% during the past century of recovery. Civilization is not correlated with dental health as it is with longevity and general health. Prehistoric diet (barley, mutton, herbs, olives, grapes, and later milk, beef, wheat) was often sparse, except for royalty, and wear-producing. Eggs and the importing of wheat improved Classical diet, but by Roman times elaborate cooking and softer food follow, with less wear, more overbites, pyorrhea, mouth retraction, and longer upper face and shorter chin. Turkish introduction of sugar in the phase of poorest health precedes modern refined flour and definite deterioration of dental microstructure (Sognnaes). With age constant dental lesions correlate clearly with wear and weakly with overbites. Face structure and diet both contribute critically to modern poor dental health.

Supported by N.I.H. grant A-224 and field grants from Guggenheim, Wenner-Gren, and American Philosophical Society.

4. *Relations of some physical properties of spongy bone to trabecular orientation.* F. Gaynor Evans and Albert I. King, Department of Anatomy, The University of Michigan and Department of Engineering Mechanics, Wayne State University.

Certain physical properties were determined for 91 standard and 15 cubic specimens of spongy bone cut in different planes from various parts of the femurs of 10 adult human embalmed cadavers. Density was determined from dry specimens but wet specimens (saline solution) were used for other physical property determinations. Trabecular orientation was based on x-rays. A variance analysis was made of the means of the physical properties of the standard specimens. The compressive stress, approximately parallel to the trabeculae, of the neck specimens exceeded that of the trochanteric specimens, regardless of loading, at the 2% confidence level. The strain and energy absorbed by the head specimens, loaded superior-inferiorly, surpassed that of the medial condyle specimens, regardless of loading direction, at the 1% and 2% levels of confidence, respectively. The energy absorbed in latero-medial loading, mostly head specimens, was greater than that in antero-posterior and superior-inferior loadings, regardless of region, at the 1% confidence level. The strain in latero-medial loading exceeded that in the neck and antero-posterior loading, regardless of region, at the 4% level of confidence. No other significant differences between means were found for stress, strain, and energy absorbed or for modulus of elasticity and density. Trabecular orientation in the head appears to influence physical properties more than in other regions.

This research was supported (in part) by Research Grant A-3865 from the National Institutes of Health, United States Public Health Service.

5. *The Ganda pelvic skeletons: a radiological and osteometric study.* David Allbrook and Elsie Sibthorpe, Makerere College, The University College of East Africa, and Washington University School of Medicine, St. Louis.

The common clinical event of obstructed labor among Ganda women prompted this study of the female pelvic skeleton in this East African lacustrine Bantu tribe.

The work involved radiological pelvimetry of 90 living subjects, and the measurement of 32 dried articulated skeletons. Though mainl Baganda both groups included individuals o closely related tribes.

On each living subject the stature was measured (mean 151.2 cm) and films were exposed t show brim, outlet and lateral views of the pelvis On these were measured the anteroposterio (mean 9.97 cm) and transverse brim (mean 11.5 cm) diameters, the symphysial height (mean 3.4 cm), the straight sacral length (mean 9.5 cm) the interischial spine (mean 10.0 cm) and pubo sacral (mean 11.0 cm) lengths, and the subpubic angle (mean 78.1°). The mean brim index was 87.6, the calculated mean brim area was 87.2 sq. cm. and the mean outlet area was 85.57 sq cm.

Similar measurements were made on the skeletal material. Comparison shows good correspondence between the two groups of measurements with the exception of the transverse diameter of the brim and the derived brim area which were significantly larger in the skeletal material.

In the skeletal material outlines of the sciatic notch obtained by projecting 35 mm film negatives were examined. The mean angle formed by the two basal and one apical points of contraflexure of the sciatic notch curve was 83°. In a comparable series of male Bantu skeltons it was 67°.

It is concluded that the average female Ganda pelvic skeleton is small in all dimensions but gynaecoid in configuration.

6. *Differences in anthropometric measurements within and between communities in Peru.* Gabriel W. Lasker, Department of Anatomy, Wayne State University.

Anthropometric measurements of 18 dimensions in 544 adults living in three towns in north Peru are analyzed. Persons (I) both of whose parents were born in a town differ significantly from residents (II) one or both of whose parents were born elsewhere in respect to 15 of 102 comparisons of means. In 13 instances (I) is significantly less variable than (II). In 102 comparisons between the three towns, natives (I) differ significantly in means in 29 and in variances in 16. These local differences are found despite admixture into the three towns at rates of 13 and 16%, 25 and 26% and 29 and 35% in the last two generations respectively. Despite the continued differences between the adult populations of the three towns there is evidence that immigration is tending to decrease the variability between towns and to increase the variability within towns.

7. *Some biological aspects of the Bushman.* Ronald Singer, Department of Anatomy, University of Cape Town, and University of Illinois.

Bio-anthropological surveys of living Bushman and Hottentot populations are providing valuable information concerning their distinctive characteristics, their relationships to each other and to other African populations, their survival patterns, etc. In this report a few of these aspects are discussed. A more detailed description is in the press (*Zeitschr. f. Morph. u. Anthrop.*).

In some respects the Bushmen are distinguished both in morphology and blood group frequencies from other African peoples, and it appears that their haptoglobin frequencies may also be unusual (Barnicot, N. A., Garlick, J. P., Singer, R., and J. S. Weiner. *Nature 184:* 2042, 1959).

The Bushmen's increasing difficulty of obtaining meat (game), has necessitated a transition to vegetable protein intake. Certain nuts and beans protect them from protein malnutrition, this beng especially important in the post-weaning phase of infants.

The correlation between malaria and bilharzia, habitat distance from the Okavango river and various clinical tests on the Bushmen is discussed.

Various diseases afflicting the Bushmen are mentioned and their survival pattern is discussed. The Bushman is a remarkable example of human adaptation to extremes in nature and environmental restrictions.

8. *Did Columbus have syphilis?* Charles W. Goff, Yale University School of Medicine, New Haven, Conn.

Two cranial specimens from the Maya Indian ruins of Zaculeu, Guatemala, found in 1947 and reported by me in 1953, in "The Ruins of Zaculeu," pp. 312–319, appeared to have gross evidence of syphilitic osteitis. They were exhaustively examined, grossly, by roentgen and serologic studies, microscopically and by comparative methods with modern known cranial bone syphilis. From these studies an important fact emerged. Syphilis had existed as a disease in the New World prior to contacts with Europeans. These skulls were dated by archeologic methods as somewhere between 600 and 900 A.D. when buried.

Much historical and recorded evidence indicates Vincente Pinzón, pilot of Cristobal Colón the Admiral, on his return from the first voyage of discovery, was treated for syphilis in Barcelona by de Isla, an Italian physician of that era. And so a second conclusion seemed obvious: that a companion of Colón was among those who brought the disease to Spain from the New World, specifically in 1493.

Through special arrangements made possible by the American Ambassador to the Dominican Republic, I examined the famous osseous remains now in the mausoleum within the Cathedral of Santo Domingo in Cuidad Trujillo, D. R. These are probably the bones of Cristobal Colón, the discoverer of the New World. Evidence of aging, size and robustness, multiple varieties of bones of a single individual and other evidence strongly indicated their authenticity. These remains, including two large cranial fragments, are without gross evidence of bony syphilis. A third fact emerged from the combined examinations: that Cristobal Colón did not have cranial bone syphilis.

Symposium

EVOLUTIONARY AND EXPERIMENTAL BIOLOGY OF THE PRIMATES

(Papers 9–15)

9. *Baboon populations in Kenya.* B. Irven DeVore, Department of Anthropology, University of California, Berkeley.

During 1959 the author accompanied S. L. Washburn on a ten-month study of the behavior and ecology of Kenya baboons (*Papio doguera*), supported by a Ford Foundation grant for the Evolution of Human Behavior. Most of the observations were made in the Nairobi Royal National Park and the Amboseli National Reserve. Baboon troops were found to range in size from 9 to 185. At Amboseli, where a census was made of 15 troops, the total number of animals was 1203; the troops varied in size from 13 to 185, with a mean troop size of 80. At Nairobi, 9 troops were found to range in size from 12 to 87, with a total population of 374, and a mean troop size of 41.5. Population density in the Nairobi Park was about 10 baboons per square mile. Density at Amboseli was higher, but these data were gathered at the end of the dry season when concentration at water holes was probably at a peak.

The home range of Nairobi troops varied from 3½ square miles (troop of 28) to 9 square miles (troop of 87). There is considerable overlapping of troop ranges, and no indication of defense of "territorial boundaries." Contact between troops in the Nairobi area is infrequent, but at Amboseli contact can be both frequent and prolonged. In neither area, however, are individuals seen to change troops (only one instance of this having been observed during this field session). No healthy, completely solitary baboons were seen.

10. *Social behavior of Rhesus monkeys.* Stuart A. Altman, Biological Laboratories, Harvard University.

No abstract.

11. *Brachyteles and the other brachiating New World monkeys.* G. E. Erikson, Department of Anatomy, Harvard Medical School.

In the course of a four months' trip in South America in the Spring of 1959, three specimens of the woolly spider monkey, *Brachyteles arachnoides* (E. Geoffroy) were collected near the Rio Doce in the state of Minas Gerais in southeast Brazil. One, a female infant, was sent back alive and is currently being exhibited in the Zoological Garden of the New York Zoological Society. This represents the first living specimen exhibited in this hemisphere, and possibly in the world. The mother of this infant and another female (subadult) were embalmed and are now being studied anatomically. These cadavera represent the first complete, well-preserved specimens subjected to anatomical investigation.

Photographs, x-ray films and anatomical data will be presented. Comparisons of *Brachyteles* with *Lagothrix* and *Ateles* will bear on the question of their genetic distinction.

The brachiating features of these three genera, and some approaches to them in *Alouatta*, will be reviewed, and comparisons will be made between these New World forms and brachiating Old World forms.

12. *The skin of primates.* William Montagna, Department of Biology, Brown University.

No abstract.

13. *Chromosomes of Old World primates.* Ernest H. Y. Chu, Oak Ridge National Laboratories.

No abstract.

14. *Chromosomes of New World primates.* Michael Bender, Oak Ridge National Laboratories.

No abstract.

15. *Hemoglobins, haptoglobins, and serum transferrins of a number of Old World primates.* John Buettner-Janusch, Department of Anthropology, Yale University.

No abstract.

16. *Richard Owen and primate studies.* Jacob W. Gruber, Temple University.

Richard Owen was born in 1804 and died in 1892. His life spanned the most significant and exciting period in the history of the natural sciences.

In the course of his intellectual travels, he met the primates. From 1835 until 1855, he produced from the wide variety of his researches a number of papers and memoirs on the primates, particularly the man-like apes whose interest was heightened not only by the dearth of information at hand but also by the undoubted affinities which they had to man. Reading this series in the order of their production, it is possible to measure the extent of Owen's contributions not only to the classification of the group, but also to the development of the significant body of data concerning their organization, functional adaptation, affinities and geological history. Owen seized upon every specimen, no matter how obtained, to construct the natural history of that near human group which "still remained almost as little understood as at the dawn of zoological science." Huxley, in his *Essay on Man's Place in Nature*, notes sadly that it had taken two and a half centuries "to arrive at the clear result that there are four distinct kinds of Anthropoids." In England, at least, no man did more to achieve that result than did Owen.

Owen's acceptance, however, of the progressionist philosophy, by which increasingly complex organic forms were assumed to have been successively created within an overall design—the very system which gave his researches meaning—made it impossible for him to accept the apparent directionless of evolution. Moreover, his assumption of the uniqueness of man as the term of that creative series led him to construct anatomical distinctions which did not exist. His insistence on the uniqueness of man and a divinely ordered organic universe in the face of the victories of post-Darwinian biology made of him an anachronism whose earlier labors were too soon forgotten.

17. *Why the marmoset grew her tail.* William E. Edwards, University of South Carolina and University of Chicago.

The caudal index (tail length/head + body length) is employed as the primary criterion of marmoset tail hypertrophy degree. Marmoset geography-ecology, morphology, and behavior (especially the unusual monogamy and transport of young by father) must all be considered in interpreting tail hypertrophy causation. Nineteen hypotheses may be deductively analyzed to determine expectable concomitant phenomena of each. There is unsatisfactory accord between requisite concomitants and empirical data for eighteen hypotheses, including those of allometric growth pattern resultant, erythrocyte production, locomotor balance, sitting support, and prehensility. The sexual-social selection postulate, however, the expectable concomitants of which include an unequal sex ratio, sexual dimorphism in tail hypertrophy, and lower caudal indices for larger species, is entirely consistent with available data.

Comparable analyses indicate that tail hypertrophy by sexual-social selection is widespread among most major divisions of the primate order.

18. *A study of dental variability in a natural population of gibbons* (*Hylobates lar.*). John E. Frisch, s.j., Department of Anthropology, University of Chicago.

It has long been recognized that an accurate knowledge of living primates forms an essential basis for a correct interpretation of the primate fossil record. Yet, data concerning the variability of the primate dentition, especially in wildshot populations, are practically inexistent. The lack of such data makes it particularly difficult to estimate the taxonomic significance of differences observed in fossil dentitions, which still constitute the major part of the fossil record.

The present study aims at filling part of this gap by describing the amount and kind of dental variations observed in a sample of 125 gibbons of the species *Hylobates lar*, collected in Thailand by the Asiatic Primate Expedition of 1938. Special attention is paid to the occurrence of extracusps, the cusp and groove patterns and the high frequency of a supernumerary root in the lower premolars.

The main conclusions are: 1. an unexpected high degree of dental variability in this natural population; 2. the majority of the observed variations occur bilaterally and thus appear to have a genetic basis; 3. teeth considered most stable in hominids may not be so in gibbons and the applicability of Butler's field concept to all the higher Primates is therefore questionable.

The implications of these findings for the interpretation of the primate fossil record are discussed and the need for similar studies of other species of gibbons is stressed.

19. *Comments on the brain of the gorilla.* Charles R. Noback, Department of Anatomy, College of Physicians and Surgeons, Columbia University.

The topography and cytoarchitecture of the brain stem (midbrain, pons and medulla) nuclei are, in general, remarkably similar to those in man. Several differences that may have functional significance are present in the gorilla examined.

The nucleus ambiguus (motor innervation to larynx and pharynx) is shorter and less cellular in this gorilla. The cellularity is low in the oral third of the nucleus, the portion which is presumed to innervate the laryngeal muscles in man.

The descending nucleus (pain and temperature of face) of the fifth nerve is divisible into three nuclei (oralis, interpolaris and caudalis) as in man, macaque and gibbon. Cytoarchitecturally, these nuclei are similar to those in man but are slightly different from these nuclei in the macaque and gibbon.

The nucleus of Perlia (convergence?) is represented by only a few scattered cells in the gorilla.

The nucleus of Edinger Westphal (light reflex and accommodation) is similar in its extent and contour as in man but the nucleus is a continuous column as in the macaque and not a discontinuous column as in man.

The cross sectional areas of the dorsal columns (proprioception etc. from body) in lower medulla are considerably larger in the gorilla (35 to 44%) than in man (29 to 31%) with respect to the total cross-sectional area of lower medulla. The functional significance is implied but not proven.

Supported by a grant from the United States Public Health Series, B-1417.

20. *Report on the new fossil site at Langebaan in South Africa.* Ronald Singer, Department of Anatomy, University of Cape Town, and University of Illinois.

The chance observation by the author of a heavily fossilized tortoise carapace in the Port Elizabeth Museum led to a visit to the Langebaan Phosphate Quarries of the African Metals Corporation. This vast site is only 10 miles north-northwest of the equally large Elandsfontein (Hopefield) site which yielded the Saldanha skull and associated artifacts and faunal remains. Commercial excavations cover a potential fossiliferous area of about 4 square miles. Previously a mass of fossil material had unfortunately gone through the stone-crushers. Among the specimens found was a portion of a right upper molar of *Stegolophodon* sp. (Singer, R., and D. A. Hooijer. *Nature, 182:* 101–102, 1958), the only other recognized African representative of this genus having been described from Sahabi in Cyrenaica, North Africa. Recently a tooth akin the Langebaan specimen was diagnosed by the author in a collection from the Kaiso Beds, then in the British Museum (Natural History). The Langebaan collection also contains Stegodont and Archidiskodont specimens.

The importance of the site is demonstrated by: (a) the material is found at depth in two major layers; (b) the upper limestone layers yield specimens similar to the nearby Elandsfontein fauna, while the lower phosphatic layers contain a far more archaic series belonging to the Middle or Lower Pleistocene; and (c) if hominid remains are found they may provide an important (? new) link in the evolutionary story in Africa.

Grants from the South African Council for Scientific and Industrial Research and the Wenner-Gren Foundation for Anthropological Research have facilitated the field work.

21. *Plesianthropus Transvaalensis: Additional facial fragments.* G. W. H. Schepers, E. I. du Pont de Nemours and Company, Newark, Delaware.

A description is furnished of two fossil fragments from the Sterkfontein bone breccia. These specimens include the posterior half of the ramus mandibularis of an adult? male. Dimensionally, it matches the jaw of *Plesianthropus transvaalensis,* enabling complete visualization of this hitherto incompletely defined part of the mandible including the condylar process and the angulus. The second specimen comprises a parasagittal portion of the facial skeleton. The plane of cleavage passed through the taurodont teeth of the right maxilla and mandible and slightly obliquely through the maxillary antrum, the orbit and the supraorbital ridge. These facial fragments match closely the dimensions and contours of adult male *Plesianthropus transvaalensis* skulls. This specimen was found at Sterkfontein, Transvaal on August 1, 1936. If accepted as a Plesianthropus, this will represent the first specimen identified.

22. *The genus Australopithecus.* S. L. Washburn, Department of Anthropology, University of California, Berkeley.

Through the kindness of Drs. Dart, Leakey, and Robinson, and with the aid of a grant from the Ford Foundation, it has been possible for me to see a large part of the australopithecine material. Structurally, there appear to be two well-defined groups, an early, small one, and a late, large one. These two forms differ no more than many species of monkeys and apes. The specimen from Olduvai is very similar to those from Swartkrans.

Large numbers of stone tools have now been found associated with australopithecines. There seems to be no doubt that at least some of these forms were making stone tools, and it is probable that all were tool users.

The situation on the bone tools is by no means so clear. Certainly most of the forms regarded as evidence for an osteodontokeratic culture can be duplicated from the remains of recent kills.

The evolutionary importance of these discoveries is that they show that tool use may be as old as bipedal locomotion, and that the increase in the size of the brain followed long after bipedal locomotion and tool use.

23. *Variation in the ABO blood groups among American Indians: A possible association with dietary differences.* Alec J. Kelso, University of Colorado.

The ABO blood genes show a rather puzzling distribution over the face of the earth. While originally the trait was thought to be non-adaptive, at the present most authorities agree that the frequencies are a consequence of adaptation. A primary difficulty arises, however, in attempting to point out specific mechanisms which might be responsible for bringing about this adaptation.

In the present paper the gene frequencies of aboriginal peoples in North and South America are analyzed in an effort to show a possible relationship between them and dietary differences. North America is divided into four major areas: (1) The Plains, (2) the boreal forest and Eskimo, (3) southern gatherers, and (4) agriculturists. South America is divided into three areas: (1) Intensive agriculture, (2) tropical forest, and (3) marginals. The samples representing each of these areas have been drawn primarily from Mourant et al. (*The ABO Blood Groups*) and include only those consisting of at least 100 individuals all of whom are believed to be entirely of Indian descent.

While there is in some instances a considerable amount of cultural variability in each area from the standpoint of productivity, each area is rather homogeneous with respect to two features: basic dietary items and ABO blood gene frequencies. On the basis of this association, the author suggests a possible real relationship between diet and the gene frequencies.

24. *ABO(H) incompatible matings: A causative factor in human infertility.* Rodger Heglar, University of Michigan.

Recent years have produced a large number of clinical and statistical population studies demonstrating the role of the ABO(H) blood group system in human fertility. These data have shown maternal foetal incompatibilities ranging from foetal loss to hemolytic disease of the newborn in its milder forms. These eliminations of incompatible offspring are the result of pregnancies due to "heterospecific" or "heteroantigenic" matings. The most frequent serological feature seen in the above cases is a group A offspring (antigen A of the male) and a group O female.

Our investigation, made possible through the cooperation of Women's Hospital and Gynecology Department of the University of Michigan Medical Center, has focused upon referred infertility cases with unknown etiology. These "refractory infertiles" comprise 10–20% of all infertilities. Blood, saliva, and semen samples were obtained from an *Infertile Couple Series* (Group I, 109 couples) and a *Fertile Control Couple Series* (Group II, 171 couples). Knowing the above blood group pattern previously encountered, the majority of the selected couples included group O women.

Recent research has demonstrated the presence of ABO(H) antibodies in cervical and uterine fluid, and ABO(H) antigenicity in sperm. The research reported here is an investigation of suspected antigen/antibody reactions at the preconceptual level involving antibodies in vaginal fluids and sperm antigens. Also, the secretor status (ABO(H) blood group substances in body fluids) was determined for couples in both series.

The serological information indicates a consistent blood group pattern of heterospecific matings involving group O wives and group A husbands among the infertile couples. Likewise, the secretor data varied from the expected ratio as the infertile series indicated more non-secretors and "aberrant" secretors than the control series of fertile couples.

25. *Blood groups of Dominicans.* Fred H. Allen, Jr. and Robert A. Milch, Boston and Baltimore.

Blood grouping tests have been done on 135 native residents of the Dominican Republic. These comprised two groups: 94 students in a seminary in Ciudad Trujillo who come from all parts of the country, and 41 residents of the town of Bani. There were marked differences in blood-group frequencies between the two groups, suggesting that the population of the Dominican Republic does not have a uniform genetic background, although the Dominicans consider themselves a distinct ethnic group (which they believe originally consisted of some European, some African and some Carib Indian stocks). Both groups tested have evidence of a large proportion of genes of African origin and no detectible trace of Indian genes.

26. *The competition between antibody-forming clones.* John Scudder, Columbia—Presbyterian Medical Center, New York City.

No abstract.

27. *The measurement of subcutaneous tissue by the Harpenden caliper and by surgical incision.* Edward I. Fry, Department of Anthropology, University of Nebraska.

The relationship between Harpenden caliper measurement of subcutaneous tissue and direct measurement of that same tissue by surgical incision provides a true test of the validity of caliper measurements of subcutaneous tissue.

Preliminary results from investigations carried out in English hospitals in the summer of 1959 indicate that the Harpenden caliper technique does accurately gauge the subcutaneous tissue depth. Nineteen subjects with an average age of 43 years, provided 55 test sites. The product-moment correlation between the caliper measurement and the incision measurement was 0.82. The mean caliper measurement was 42% of the doubled incision mean.

Further investigations along these lines are being carried out on surgical patients and autopsy subjects in the U.S.A.

28. *A new model of skinfold caliper.* K. O. Lange and Josef Brozek, Wenner-Gren Aeronautical Research Laboratory, University of Kentucky, and Lehigh University.

Body fat is one of the most "dynamic" components of human physique, exhibiting systematic trends with age as well as intra-individual changes associated with change in mode of life (food intake, activity) and with disease. The inter-individual differences are large and the appraisal of their significance for the maintenance of health, longevity and development of specific degenerative (non-congenital, non-infectious) diseases is an important, unfinished task.

The subcutaneous fraction of the total body fat is accessible to anthropometric appraisal through skinfold measurements. In answer to persistent demands for a light compact skinfold caliper an instrument was developed with the following characteristics.

A slender handle held in the natural (right) hand position is opposed by a thumb lever. Thumb pressure on this lever opens two jaws uniformly in opposite directions to receive the skinfold. Maximum opening is over 6 centimeters. Upon release of the thumb the jaws clamp onto the skinfold by means of two opposed tips of approximately 30 square millimeters contact area. An internal spring arrangement causes the contact pressure to be 10 grams per square millimeter irrespective of the thickness of the skinfold. The reading of the thickness of skinfold under this pressure is obtained by noting the position of the fine pointer on a semicircular dial, 2.5 inches in diameter, with an almost linear scale, with divisions of 150% of natural size.

29. *A new method of osteometry.* Harry Wood O'Dell, The Akron Clinic, Akron, Ohio.

This method utilizes the principle of triangulation and employs a grid between the target and the x-ray tube. The grid is placed halfway between the tube and the target by means of a lazy tong apparatus. Computation is not necessary as the grid is constructed to scale. The length of bone can be read directly from the film as the grid lines are numbered. Special cassettes are not necessary for a small cassette is placed under each end of the bone. Only one exposure is necessary. In children the entire extremity can be measured with one exposure. A checkerboard grid is used for hip measurement in preparation for the use of a prosthetic device. The method was tested by measuring intra-medullary rods which were embedded in fractured femora.

30. *The relative efficiency of measurements for determining race and sex in human crania.* Orville Elliot and Eugene Giles, Department of Anthropology, Harvard University.

Discriminant functions based on 11 cranial measurements on 300 skulls from the Todd and Terry collections of human skeletal material were calculated to differentiate Whites and Negroes for both males and females. The calculations were done on electronic punch card equipment which permitted multivariate analyses not feasable by desk calculator techniques.

The analyses show that the culturally defined categories of White and Negro can be distinguished in the skull with a high degree of accuracy by use of metrical characteristics. Identification of race by this procedure compares favorably with previous results obtained by quantitative observations of morphological criteria.

The results indicated the discriminant efficiency of each individual measurement as well as the discriminant function as a whole. An independent test was done on the accuracy of race identification by means of 108 skulls not included in the original calculations. The relative utility of 10 of these measurements for the determination of sex in both races was also ascertained.

31. *Discriminant functions for the morphological sexing of human skulls.* Eugene Giles and Orville Elliot, Department of Anthropology, Harvard University.

Ten cranial dimensions (length, breadth, basion-bregma height, nasion-basion, nasion-prosthion, basion-prosthion, mastoid length, opisthion-forehead maximum, bizygomatic breadth, palate breadth) have been measured on a sample of over 400 known-sex skulls from the Terry and Todd skeletal collections. From various combinations of 5 to 10 of these measurements 28 discriminant functions have been calculated to provide the maximum possible differentiation between the sexes in Negroes, Whites, and both races combined. The probability of misclassification has been determined for each discriminant function. The sex of a skull can be determined by taking similar measurements, multiplying them by the corresponding coefficients of the discriminant function, and noting whether the sum falls on the male or the female side of the sectioning point. Seventy-five specimens of each of the 4 race and sex combinations were used in the calculations, the remainder provided an independent check.

32. *Contourometry: A novel anthropometric technique.* K. O. Lange, Wenner-Gren Aeronautical Research Laboratory, University of Kentucky.

Early anthropometric devices to describe the living head and body forms were simple calipers and head spanners. The "Cartesian faceometer," developed in 1952, permits the rapid measurement of selected reference points of the human head by X Y Z coordinates. In order to minimize the time of observation on a subject, to avoid distortion by mechanical pointers, and to obtain continuous measurement or reproduction the "Lange-USAF contourometer" was subsequently developed.

The apparatus consists essentially of two parts, namely a contour-producing stroboscopic light unit and a photographic unit. It permits to reproduce clear contour lines on the human head from 4 directions with various depth spacings, thus recording complete topographic maps of the head form and size. A system was devised to super-impose upon the record a grid for direct reading in rectilinear coordinates.

At first satisfactory contours could be obtained only where the camera could see and record on the camera side of the body parts, but later, with support of the United States Army, a contourometer was developed which permits to photograph "hidden" contours by means of oblique mirrors. The distorted pictures thus obtained are then reprojected through the same apparatus into the original plane of the contours. In that way contours of natural size are produced either on a screen or on photographic paper.

Using this principle, a small and semi-portable contourometer was built which permits the reproduction of horizontal cross-sections through heads or hands or feet.

33. *The presentation of anthropometric data in three-dimensional forms.* Milton Alexander, Capt. Robert S. Zeigen and Irvin Emanuel, Anthropology Section, Aerospace Medical Laboratory, Wright Air Development Division, Dayton, Ohio.

The Anthropology Section, Wright Air Development Division, has used new as well as standard approaches in the attempt to translate anthropometric data into three-dimensional forms. Basic anthropometric data must be interpreted for the designer and engineer prior to their application to practical problems. One recognized method of presentation is summating each dimension under its mean, standard deviation and percentiles. This approach has been proved quite acceptable for workspace situations concerned with gross measurements. On the other hand, considerable confusion exists among designers and engineers when it comes to handling anthropometric data for items of close-fitting protective equipment, e.g., pressure suits, oxygen masks and helmets. In the past, various head and body forms have been fabricated to provide the designer with more concrete expressions of anthropometric data. Recent efforts along these lines have led to the development of new three-dimensional forms, some for general application and others for specific problems. All of the current approaches employ key dimensions chosen to determine size ranges. Items included under this program are (1) a series of faceforms (key dimensions are total face length and lip length), (2) two series of headforms (both using head circumference as the key dimension), and (3) a series of body manikins (based on height and weight). The special set of faceforms has been used to size a new light-weight oxygen mask; the two headform series are in use for the experimental sizing of various helmets; and the body manikins are being fabricated to represent a range of body sizes using a height-weight system for flight clothing. The design rationale on which these forms are based and the difficulties encountered in sculpturing them to dimension are discussed.

34. *Heights and weights of white Americans.* Howard W. Stoudt, Albert Damon and Ross A. McFarland, Department of Industrial Hygiene, School of Public Health, Harvard University. (Read by Robert M. White.)

The need for height and weight data on a population, always useful for nutritional, physiological, and public health purposes, has recently become acute in the fields of radiation protection and "human engineering." Based on published and unpublished studies made since 1940, some by ourselves, means and standard deviations are presented for white males and females in the United States from birth to old age.

35. *Aerospace applications of physical anthropology.* Richard G. Snyder, Applied Research Laboratory, University of Arizona.

The efforts to place man in the new astroecological environment of space poses many problems for which limited knowledge, or in many instances no knowledge at all, exists. As a consequence the associated biological problems should challenge and stimulate the physical anthropologist in both basic and applied research areas. Consideration of some of the factors involved within the scope of aerospace anthropology are discussed. Selected aspects of current and possible future research are discussed in regard to hypersonic escape and protection, force stresses and human tolerance to acceleration, vibration, oscillation, weightlessness, seating and support systems, the closed ecological system, body composition and physique criteria, and certain other biological and cultural relationships inherent in a manned space vehicle. Some areas of research where the physical anthropologist, more than perhaps any other discipline, may offer particularly important contribution in current and future investigations are suggested.

36. *The anthropometry of Army aviators: A preliminary report.* Robert M. White, Quartermaster Research and Engineering Center, Natick, Massachusetts.

An anthropometric survey of Army aviators was recently completed by the Quartermaster Corps. In this survey, measurements were obtained on a series of 500 pilots, which represents a 10 per cent sample of the Army aviator population. Forty anthropometric measurements were taken on each man; these data have been analyzed for application in the design, sizing, and human engineering of clothing and equipment in the field of Army aviation.

37. *A photographic method of grading variations in skin color.* Leo Estel, Department of Sociology and Anthropology, Ohio State University.

The major factor in variations in skin color is variation in the amount of the brown pigment, melanin. Increase in amount of melanin results in a darkening of the skin. By proper juxtaposition of a standard gray scale in the making of black and white photographs of skin color a satisfactory grading to a 7 point scale can be made. The method does not require an exceedingly exact control of exposure and development and standard commercial film and service can be utilized. Very successful results have been obtained with a Polaroid Land camera which will be used for demonstration purposes.

Symposium

THE TEACHING OF PHYSICAL ANTHROPOLOGY

(Papers 38–42)

38. *Introduction.* David Mendelbaum and Stanley M. Garn, University of California, Los Angeles, and Fels Research Institute.

No abstract.

39. *Objectives and concepts.* Frederick P. Thieme, University of Washington.

No abstract.

40. *Design of courses.* Edward E. Hunt, Jr., Department of Anthropology, Harvard University.

No abstract.

41. *Techniques of teaching physical anthropology.* F. S. Hulse, Department of Anthropology, University of Arizona.

The techniques used in teaching physical anthropology will undoubtedly vary in accordance with the aims and interests of the teacher, as well as with the resources available to him. It is universally agreed that laboratory work of some nature is required on all but the most elementary level, if not even there. Audiovisual resources should be exploited extensively. Individual and/or class projects ought to be encouraged as much as possible. A variety of types of equipment must be available, because of the diverse sorts of research used in physical anthropology. The one absolutely necessary piece of equipment, however, is a teacher trained in physical anthropology.

42. *Discussion.* W. Montague Cobb and Wilton M. Krogman, Department of Anatomy, Howard University and Philadelphia Center for Research in Child Growth.

No abstract.

43. *Presentational methods.* D. L. Polacheck, Tri-County College, Saginaw, Michigan.

Papers are presented with communication as the aim. Regardless of scientific content or subject field, the research report succeeds or fails as the presenter communicates or fails to do so.

Comment will be offered on presentational methods in two areas: graphic material, and, paper delivery (non-newsboy department). That specific reference to the efforts of physical anthropologists will be made, is to be understood.

44. *P.A. on T.V.* Charles E. Snow, Department of Anthropology, University of Kentucky.

The regular introductory course in physical anthropology at the University of Kentucky was televised by open circuit beginning the fall semester, 1959, to an assembled class of 150 on the campus at the University, to extension students who viewed sets at home, and to the community at large. It is being repeated for the second time this spring semester.

This experimental production was sponsored by the University of Kentucky Broadcasting Service and the Department of Radio Arts, College of Arts and Sciences. It would appear to be a first in physical anthropology. It is noteworthy that a commercial station—WLEX—donated the time—9:00 to 10:00 A.M. Monday, Wednesday, and Friday—as a public service.

There are many unique advantages to TV once the instructor successfully substitutes the camera for the responsive (and sometimes sleeping) faces of students. Demonstration models, casts, and illustrations on cardboard, slides and/or movies are visible screen-size to all viewers. (Even Prokofiev's music and fade-out filmed introduction were used.) There's "no limit" to the number of viewing students; indeed, one partially blind boy achieved a C. Five tests during the semester showed similar curves to large-sized classes of past years, and the belief is that no student at U.K. ever saw more physical anthropology better.

It is believed that the "no show" interruption (one complete show and one-third of another) was no more worrisome than ordinary classroom absence due to illness, bad road conditions, and other teacher hazards.

The effectiveness of the program as a whole has proved beyond our greatest hopes and indicates a stimulation throughout the community that augers well for a better understanding of anthropology as well as opening new vistas to career-seeking pre-college students.

45. *A preliminary report on the variation in cranial types of the aboriginal plains Indians.* William M. Bass, Department of Anthropology, University of Nebraska.

Our present knowledge of the protohistoric Plains Indians stems mainly from archaeological material, ethno-historical documents and ethnological data from living Indians. Much is known about the culture and habits of the Plains Indians prior to the coming of the white man. Archaeological excavations since 1946, the result of reclamation and flood control projects in the Missouri River Basin, have contributed tremendously to our knowledge of the Indian cultures in the Plains. But, at the present there is little published scientific work on the physical types of the Indians themselves. We know much about their culture but very little about their physical appearance.

The author began two years ago a research project supported by the Smithsonian Institution and a grant from the Anthropology Department of the University of Pennsylvania to gain basic information on the physical types of the protohistoric Plains Indians. Measurements and observations were made on the human skeletal material of over 2000 individuals from the Missouri River Basin area. A preliminary analysis of the adult male skulls from three (Arikara, Pawnee and Aksarben (Upper Republican and Nebraska culture)) of the larger related groups within this area will be reported. A statistical analysis attempting to arrive at a quantitative measure of biological differences between groups will be discussed.

46. *The incidence of cervical ribs in North American Indians.* Clyde C. Snow and Loudell M. Fromme, Department of Anthropology, University of Arizona.

The incidence of cervical ribs in a sample of over 3000 North American Indians is presented, based on a review of chest roentgenograms. Tribes included in the sample are Arapaho, Chippewa, Haida, Papago, Pima, Shoshone, Sioux, Tsimshian, and Tlingit. There appears to be little difference in the frequency of this anomaly between the various tribes. Among all of them, however, it appears more often than among series of Europeans or Africans which have been examined. A tendency towards familial occurrence of cervical ribs is noted, and supports a genetic basis of the anomaly proposed by European investigators.

47. *A reappraisal of the age and sex of the Indian Knoll skeletal population with some additional notes on the correlation of tooth wear and age.* Francis E. Johnston, Philadelphia Center for Research in Child Growth.

The Indian Knoll skeletal population, consisting of over 1200 individuals, is located at the University of Kentucky and the U. S. National Museum. This group comes from a Kentucky shell mound of the Eastern Archaic archaeological period and has been dated at 4900–5300 years of age by the Carbon 14 method. It is one of the largest homogeneous skeletal collections available in the country.

During the summer and fall of 1959, the largest portion of the population, located at Kentucky, and numbering over 900 skeletons, was reexamined by the author in collaboration with Charles E. Snow and a new age and sex count made.

Sexing was based primarily upon pelvic characters with skull and long bone indicators used secondarily. Due to a marked sexual dimorphism in the pelves, it is felt that the correct sex was assigned in the great majority of cases.

Aging was accomplished using the latest published criteria, including the McKern and Stewart standards for the pubic symphysis. Previously, the series had been aged by means of observation of cranial suture closure. A comparison of these earlier figures with the present study shows a significant increase in the average age, particularly in the young adult range.

Tooth wear was recorded as an indicator of advancing age. At Indian Knoll, this wear reached extreme stages and, working within this series, a good age estimate could be made based on dental characters.

Finally, detailed studies were begun on the age and order of epiphyseal union in the sub-adults and the growth of long bones in the infants.

48. *A preliminary report on the odontology and occlusion of the Eskimos of the eastern Canadian Arctic.* Lawrence Oschinsky and Roy Smithurst, National Museum of Canada, and Indian and Northern Health Service, Ottawa, Canada.

The most detailed studies of the dentition of Eskimos and related people have been done in Greenland and the Aleutian Islands while the Eastern Arctic of Canada has remained a terra incognita odontologically. The writers had the opportunity during the months of July, August and September, 1959, to visit Eskimo settlements throughout the Eastern Arctic and conduct an investigation of the incidence of shovel-shaped incisors and certain aspects of maxillary lateral incisor crowding in order to compare these data with work already done in the Arctic.

The most frequent occlusal type with reference to the relationship of the incisors is an edge-to-edge or labidodont condition. Overbite or scissor bite occurred in only 0.4 per cent of the sample. Protrusive mandible or Class 3 malocclusion, according to Angle's classification, also occurred in 0.2 per cent. In approximately 33 per cent of a sample of 2,000 Canadian Eskimos a situation obtains wherein the lateral maxillary incisors are displaced lingually in relation to the central incisors, i.e., "in-standing lateral incisors." This condition was found to occur in every Eskimo settlement visited, and varied from 22 per cent to as high as 40 per cent in each population.

The frequency of shovel-shaped incisors among 499 Eskimos representing a sample drawn from various settlements of Baffin Island, Hudson's Bay, etc., amounted to 99.2 per cent which is consistent with other data on the Aleuts and Eskimos as well as Mongoloids in general. It is interesting that the distribution of shovel-shaped incisors and the above mentioned malocclusion should occur so uniformly over such a wide area in more than 17 small breeding populations which are relatively isolated. Since these characters are polygenetically determined, they are less subject to changes in frequency caused by genetic drift and so are more reliable in the determination of racial affinities of populations.

49. *Semicircular canal rotation in bipedal rats.* Melvin L. Moss, Department of Anatomy, College of Physicians and Surgeons, Columbia University.

Certain evolutionary changes in cranial morphology are associated with the acquisition of bipedal posture and locomotion. Special emphasis has been placed on the constant orientation of the semicircular canals in space throughout these morphological alterations (see: Delattre and Fenart, Z. *Morph. Anthrop.*, *49:* 90–114, 1958). The following experimental data provide substantial support for their hypothesis.

Characteristic rotations of the otic capsule regularly occurred following amputation of either the fore or hind limbs of the neonatal rat. These spatial changes altered the position of the semicircular canals relative to the reference plane of the cranial base.

Following amputation head carriage was altered; up and back with the forelimbs removed, down and forward with the hind limbs removed. In all cases the otic capsules rotated in the opposite direction. This compensatory motion seemingly kept the semicircular canals in a normal spatial orientation. Such capsular motions were accompanied by similarly directed rotations of the post-tentorial fossa, at the region of the anterior lambdoidal suture. No other cranial changes were observed.

Seemingly, an alteration of the post-cranial skeleto-muscular system leading to erect posture by itself would be sufficient to cause a passive, mechanical rotation of the otic capsule within the now elevated head.

Aided in part, by a grant B-965-(C-4), National Institutes of Health.

50. *Demographic aspects of the extinct Sadlermiut Eskimos.* W. S. Laughlin, C. F. Merbs and W. H. Wilson, Department of Anthropology, University of Wisconsin.

The Central Eskimos differ from Alaskan and Greenlandic Eskimos in their blood group frequencies more than Alaskan differ from Greenlandic Eskimos. Among the possible contributing factors are: (1) preservation of frequencies characteristic of an earlier strain of Eskimos (e.g., Dorset), and (2) alteration of frequencies attributable in part to small size of isolates, infrequent contact between them, and comparatively frequent extinction of some isolates. It is suggested here that early age at death with reduced overlap between generations, within small isolates which had both a high degree of relationship between members and inbreeding, contributed to the genetic instability of such isolates.

The recovery of a large series of skeletons from Native Point, Southampton Island, N.W.T., Canada, provided the opportunity of examining the sex and age composition of a group of Central Eskimos and of comparing it with series from ecologically richer areas of greater population density. The Sadlermiut, numbering less than 70, became extinct as an isolate in the spring of 1903. The best comparable data is that of Unalaska Aleuts reported in 1840 by I. Veniaminoff in which he gives the age at death of 491 Aleuts. The maximum age at death among the Sadlermiut appears to have been 45 years. Among the Aleuts, in marked contrast, the maximum age at death was between 90 and 100. There is a mean difference in age at death for adults of approximately 15 years. Infants and children to 4 years of age comprise some 45 per cent of the Sadlermiut series of 136 individuals, contrasted with 20 per cent of the Aleut series. It is concluded that age and sex composition in extinct isolates contributes to understanding genetic differences among contemporary members of the Eskimo-Aleut stock.

Skeletal material recovered by the University of Wisconsin field party in the summer of 1959; this and subsequent analysis is supported by the National Institutes of Health (RG-6321).

51. *Pelvic ossification and dentition in the Sadlermiut Eskimos.* William H. Wilson, Charles F. Merbs and W. S. Laughlin, Department of Anthropology, University of Wisconsin.

The skeletal material utilized in this study is that of the Sadlermiut Eskimos of Native Point, Southampton Is., N.W.T., Canada. Only those that could be aged and sexed with a high degree of probity were used. The pubic symphysis, endocranial suture closure, and dentition were employed to estimate skeletal age. The pelvis and cranium were used to determine sex. The material thus obtained consisted of 143 individuals, broken down as follows: adults 69 (29 males, 40 females); adolescents and children 13; infants 61.

No significant difference could be found between adult males and females for age of death, with means for both centering on 35 years. The most significant feature of the population profile is the abundance of infants and the deficiency of adolescents and children.

The pelvic ossification of adolescents, children, and young adults showed a uniform retardation in the pubic-ilium element, which was not fused as late as 27 years in one case.

The dentition revealed a high frequency of early tooth loss, abscesses, dry sockets, and senile atrophy of the mandible. However attrition was at a minimum and dental caries were rare. A detailed analysis of dental emergence and pelvic ossification will be discussed.

Skeletal material recovered by the University of Wisconsin field party in the summer of 1959; this and subsequent analysis is supported by the National Institutes of Health grant RG-6321.

52. *The vertebral column of the Sadlermiut Eskimos.* Charles F. Merbs, W. H. Wilson and W. S. Laughlin, Department of Anthropology, University of Wisconsin.

The collection of 63 adult (28 males, 35 females) and 8 adolescent vertebral columns used for this study are those of the Sadlermiut Eskimos recovered from Native Point, Southampton Island, N.W.T., Canada. The columns were grouped according to age as determined by the pubic symphysis, endocranial suture closure, epiphyseal union, and dentition; according to sex as determined by the pelvis; and into three successive series indicated by the archeological evidence.

The presence and intensities of certain anomalies and pathologies were plotted against age, and were recorded along with the numbers of vertebrae and sacral measurements.

Some of the characteristics found were numerical variations, spina bifida, spondyloschisis, vertebral fusion, incomplete centra, osteoarthritis, and osteophytosis.

Of particular interest was the high incidence of spondyloschisis found in 32% of males and 14% of females. The modal type of sacrum, found in 47% of the columns, was composed of 5 sacral units and a fused coccygeal unit. The hiatus of the sacral canal was correspondingly one unit larger in this sacrum. Osteophytosis was present in 75% of the columns occurring with greater frequency among the males, especially in the cervical and lumbar areas.

Etiology will be discussed and comparisons made with other groups with special emphasis on the Alaskan Eskimo samples.

Skeletal material recovered by the University of Wisconsin field party in the summer of 1959; this and subsequent analysis is supported by the National Institutes of Health grant RG-6321.

53. *Parental body build and the developmental progress of the offspring.* Stanley M. Garn, Lina Landkof and Arthur K. Clark, Fels Research Institute.

Differences in growth rate and maturational progress have been reported for adolescents differing in body build. However inevitable problems of body "typing" and the obvious confusion between maturational status and body build have obscured the meaning.

In the present study the parental mating phenotypes LL and SS were set up, using the bony chest breadth as measured on radiographs as a highly reliable measure of the fat-free mass. Approximately 90 offspring of LL and SS mating phenotypes were then compared as to growth, maturation and motoric development over a 17-year period.

For both sexes children of LL parents were longer during the growing period (without reversal in trend) and the weights of the two groups were markedly different, approximating 1 SD from ages 1 year through 16. Children of the LL parents were similarly advanced in the number of carpal centers at 1.5 and 3.0 years, in completion of carpal centers and bone age (Greulich and Pyle) at 11.0 years.

Advancement in motoric development was shown by the consistent tendency of the LL children to score higher in Gesell items at 6, 12 and 18 months, Merrill-Palmer scores at 18 and 24 months and in the early Stanford-Binet scores.

The evidence would suggest that preselection of parental mating phenotype is associated with a marked difference in the growth pattern of the offspring including not only size progress but also those aspects of motoric development correlated with developmental advancement and greater muscle mass.

Supported in part by grant M-1260 from the National Institutes of Health.

54. *Limitations of the number of hand-wrist ossification centers as an indication of developmental status.* Christabel Rohmann and Stanley M. Garn, Fels Research Institute.

The number of hand-wrist ossification centers present at a given age is utilized directly or indirectly as a measure of maturation in numerous systems. Implicit in such uses are assumptions of predictability and reliability, and the further expectation that hand-wrist ossification centers are representative of the body as a whole.

With limited variability in the number of centers prior to the first year and after the third, a hand-wrist count has useful meaning only from 1.5 through 3.0 years of age. Moreover, intercorrelations involving the number of hand-wrist centers at various ages are relatively low, averaging from 0.4 to 0.7 over a two-year interval.

While the hand does not predict itself adequately over more than one year period, correlations between the number of hand-wrist centers and the rest of the body are similarly modest, averaging 0.3 to 0.5 from two through 6 years of age. Although the hand is thus not necessarily representative of the body, the data do not indicate whether it is more or less useful than the remaining centers as a maturational indicator.

Since the carpal centers are non-contributory to prediction, improvement could be effected by limiting the count to selected metacarpal and phalangeal nuclei. Nevertheless, the low interrelations and abberant sequences of ossification limit the utility of methods that depend upon the presence or absence of centers, the center with the highest age equivalent, or a system involving arbitrary weighting.

Supported in part by Grant A-3816 from the National Institutes of Health.

55. *Tendinitis; with special reference to the shoulder.* Beckett Howorth, Stamford, Conn.

Tendinitis is a common affliction of man, and has been known for a hundred years. The shoulder is most often affected, but the elbow, wrist, or other areas may be involved, and multiple involvement sometimes occurs. This is the most frequent cause of pain and disability in the adult shoulder in the United States. How common is it in other civilized regions, in primitive man or in man with primitive occupations, has it always been an affliction of man, and does it affect animals?

The anatomy and pathology of the lesion are described. Sometimes calcific deposits occur, especially at the shoulder. The symptoms, signs, stages and course of the disease, and its roentgenographic findings are reported. Treatment is mentioned briefly.

56. *Uterogestation, headsize, and exterogestation in man.* Ashley Montagu, Princeton, N. J.

The headsize of *Homo sapiens* at term is such that it has reached its maximum limit consonant with being able to pass through the birth canal. As it is that size constitutes a hazard in many cases. The fetus must therefore be born when its head has attained the limit of size. It is born in an extremely immature condition, and will take 8 to 10 months before it can even crawl. It is suggested that the traditional notion of the gestation period as terminating at birth is a calendric and unbiological interpretation of the facts, and that birth constitutes the bridge between gestation within the womb and gestation continued for about 8 to 10 months outside the womb.

57. *Influence of the survival of the Linnaean fallacy on the classification of human races.* Leo A. Estel, Department of Sociology and Anthropology, The Ohio State University.

In general usage the idea of race in man is a slight modification of the scheme of classification proposed by Linnaeus in his "Systema Naturae." The white race (Caucasoid): the yellow race (Mongoloid): the black race (Negroid): sometimes added the australian race (Australoid): with less frequency red race (American Indian) and the brown race. Within any one of these so-called races the biological variation is very much greater than among the archetypes or ideal types set up to typify the various races.

At the time of Linnaeus the amount of factual data available was inadequate and he was forced to reply to a great extent on tales told by travelers. His system of classification was archetypal and not phylogenetic. The scheme was based on the idea of special creation. The idea of organic evolution was not acceptable.

At the time of Linnaeus the idea of the "Scala Naturae" or Great Chain of Being was in force. This arraigned all forms of life on a scale of creation with a value connotation. While this value scheme was not an implicit part of the Linnaean scheme of classification the connection was soon made.

As a result we have a value scheme of races based on completely inadequate data and knowledge. In spite of the advances in knowledge achieved by modern scientific endeavor the fallacious scheme of Linnaeus is still a major force in modern thinking on race and the imposition of the value scale of the "Scala Naturae" is responsible for a great amount of conflict and tension between nations and within national boundaries.

58. *Comparative anatomy of the posterior aspect of the knee joint.* Emanuel B. Kaplan, Department of Anatomy, College of Physicians and Surgeons, Columbia University.

The structures of the posterior aspect of the knee joint were compared in a prosimian represented by a brown lemur, Rhesus, gibbon, chimpanzee and man. This was supplemented by a study of the posterior aspect of a monotreme represented by an oranithorrhyrunchus, marsupial, machropus and carnivora: cat, lion cub and American bear.

The study was concerned with the capsular structures of the posterior aspect of the knee in relation to the gastrocnemii and the popliteus in their role of function of the knee joint. The presence and absence of the sesamoids in different species were noted. The role of the collateral ligament was studied in relation to the erect position of the lower extremities. A special structure near the fabello-fibular ligament present in men and its significance was described.

59. *Artificial thickening of bones and the Piltdown skull.* Ashley Montagu, Princeton, N. J.

Suspecting that the thickness of the Piltdown cranial bones had also been faked, an attempt was made to artificially thicken the perfectly normal skullcap bones of a human male adult, deceased some thirty years ago. For this purpose part of the skullcap was immersed in a solution of potassium hydroxide (4½ ounces of potassium hydroxide in 36 ounces of tap water). Less than 4 days from the immersion the bone swelled very markedly in thickness. The bone was so softened that a large part of it detached itself from the main portion. Since the experiment has just been concluded it is not possible to provide exact measurements, but quite clearly the thickness has increased by more than half again. It is suggested that the thick skullcap bones of the Piltdown skull were produced by some such means as the above.

60. *The morphologic variation of the supramastoid crest and tubercles.* Teuku Jacob, Department of Anatomy, Howard University.

No abstract.

61. *The geographical and ecological history of New World primates.* William E. Edwards, University of South Carolina and University of Chicago.

In the terminal Oligocene or earliest Miocene, grasses originating in the central Eastern Hemisphere spread to the south from northern North America with associated fauna. Regardless of immediately prior distribution, all American lemuroids and tarsioids (already geographically and phylogenetically reduced) were rapidly restricted to tropical forest. Larger land mass and population for the grassland fauna in time made possible further adaptive radiations, perhaps by the middle Miocene, thereby extinguishing remaining primates.

Between the middle Eocene and this extinction time, however, pre-platyrrhines had initiated crossing by natural raft to South America, probably via widely spaced islands. These migrants (probably only one group) likely did not arrive until the early or middle Miocene, despite the Argentinian discovery of a supposed late Oligocene hapaloid. About First Glaciation times, the halves of the Western Hemisphere were rejoined, after a 70,000,000-year or longer separation; some platyrrhines then contracted geographically and numerically, while others spread as far north as southern Mexico.

The long-preplexing phenomenon of absence of grassland primates in South America is thus probably best explained by arrival after grasslands and indigenous faunal preoccupation and adaptation. Possibly, however, grassland primates occurred but were extinguished during the Pleistocene by more efficient predators or competitors of North American derivation.

62. *Sprengel's deformity: a landmark on the path of human evolution.* Robert J. Terry, Department of Anatomy, Washington University School of Medicine, St. Louis.

(Read by title.)

63. *Phylogeny of some structures in the human brain.* Charles R. Noback, Department of Anatomy, College of Physicians and Surgeons, Columbia University.

(Read by title.)

BENEFACTORS

Wenner-Gren Foundation
for Anthropological Research, Inc.

The Wistar Institute
of Anatomy and Biology

RECORD OF MEETINGS AND OFFICERS

Number	Year	Place	President	Vice-Pres.	Sec'y-Treas.	Executive Committee			Editor
						1	2	3	
1	1930	Charlottesville	Hrdlička	—	Morton	Terry	Gregory	Hooton	Hrdlička
2	1930	Cleveland	Hrdlička	—	Morton	Gregory	Hooton	Todd	Hrdlička
3	1932	Washington	Schultz	—	Morton	Hooton	Todd	Gregory	Hrdlička
4	1932	Atlantic City	Schultz	—	Morton	Todd	Gregory	Michelson	Hrdlička
5	1934	New York	Pearl	—	Shapiro	Gregory	Michelson	Todd	Hrdlička
6	1935	Philadelphia	Pearl	—	Shapiro	Gregory	Todd	Boas	Hrdlička
7	1936	New Haven	Hooton	—	Shapiro	Todd	Boas	Pearl	Hrdlička
8	1937	Cambridge	Hooton	—	Shapiro	Boas	Pearl	Field	Hrdlička
9	1938	Pittsburgh	Todd	—	Shapiro	Pearl	Field	Hooton	Hrdlička
10	1939	Philadelphia	Terry	—	Howells	Field	Hooton	Pearl	Hrdlička
11	1940	New York	Terry	Shapiro	Howells	Hooton	Pearl	Krogman	Hrdlička
12	1941	Chicago	Gregory	Shapiro	Howells	Terry	Krogman	Schultz	Hrdlička
13	1942	Cambridge	Gregory	Weidenreich	Washburn	Krogman	Schultz	Shapiro	Hrdlička
14	1945	Philadelphia	Davenport	Weidenreich	Washburn	Schultz	Shapiro	Steggerda	Stewart
15	1946	Cleveland	Weidenreich	Krogman	Washburn	Shapiro	Steggerda	Straus	Stewart
16	1946	Chicago	Krogman	Steggerda	Washburn	Straus	Dupertuis	McCown	Stewart
17	1948	Washington	Krogman	Steggerda	Lasker	Dupertuis	McCown	Coon	Stewart
18	1949	Philadelphia	Krogman	Cobb	Lasker	McCown	Coon	Washburn	Howells
19	1950	Boston	Stewart	Cobb	Lasker	Coon	Birdsell	Angel	Howells
20	1951	Ann Arbor	Stewart	Dupertuis	Lasker	Birdsell	Angel	Garn	Howells
21	1952	New York	Washburn	Dupertuis	Reynolds/ Angel	Angel	Garn	Snow	Howells
22	1952	Philadelphia	Washburn	Trotter	Angel	Garn	Snow	Goff	Howells
23	1954	Yellow Springs	Straus	Trotter	Angel	Snow	Goff	Stewart	Howells
24	1955	Philadelphia	Straus	Cobb	Angel	Goff	Stewart	Spuhler	Washburn
25	1956	Chicago	Trotter	Cobb	Angel	Stewart	Spuhler	Howells	Washburn
26	1957	Ann Arbor	Trotter	Birdsell	Spuhler	Evans	Howells	Boyd	Washburn
27	1958	Cambridge	Cobb	Birdsell	Spuhler	Howells	Boyd	Greulich	Laughlin
28	1959	Madison	Cobb	Angel	Hunt	Boyd	Greulich	Thieme	Laughlin
29	1960	Washington	Greulich	Angel	Hunt	Howell	Thieme	Lasker	Laughlin
30	1961	Columbus	Greulich	Lasker	Stewart	Howell	Thieme	Goldstein	Laughlin

MEMBERS[1]

(Life members are indicated by an asterisk; recently deceased members by dagger.)

Acheson, Dr. Roy M., Social and Preventive Medicine Unit, Guy's Hospital, London S.E. 1, England.

Adams, Mr. William R., 707 Anita Street, Bloomington, Indiana.

Aginsky, Dr. Burt W., 911 Park Avenue, Apartment 10-B, New York 21, New York.

Aginsky, Dr. Ethel G., 911 Park Avenue, Apartment 10-B, New York 21, New York.

Agogino, Dr. George A., Department of Sociology and Anthropology, University of Wyoming, Laramie, Wyoming.

Alexander, Mr. Milton, P.O. Box 291, Fairborn, Ohio.

Allbrook, Mr. David, Department of Anatomy, Washington University, 4580 Scott Avenue, St. Louis 10, Missouri.

Allen, Dr. Fred H., Jr., 332 Longwood Avenue, Boston 15, Massachusetts.

Anderson, Dr. J. E., Department of Anatomy, University of Toronto, Toronto 5, Canada.

*Andrews, Dr. James M., 4860 Linnean Avenue, N. W., Washington 8, D. C.

Angel, Dr. J. L., Jefferson Medical College, 307 S. 11th Street, Philadelphia 7, Pennsylvania.

Avis, Dr. Virginia, Department of Anthropology, University of Washington, Seattle, Washington.

Baby, Mr. Raymond S., Ohio State Museum, Columbus 10, Ohio.

Baer, Mrs. Frances, 2702 Wisconsin Avenue, N.W., Apartment 500, Washington 7, D. C.

Baer, Dr. Melvyn J., The Merrill-Palmer Institute, 71 East Ferry Avenue, Detroit 2, Michigan.

Baerreis, Dr. David A., Department of Anthropology, Sterling Hall, University of Wisconsin, Madison 6, Wisconsin.

Bailey, Dr. Ralph C., c/o Box 3900, Miami, Florida.

Baker, Dr. Paul T., Department of Sociology and Anthropology, Pennsylvania State University, University Park, Pennsylvania.

Bakwin, Dr. Harry, 132 East 71st Street, New York 21, New York.

*Ball, Dr. Robert P., Oak Ridge Hospital, Oak Ridge, Tennessee.

Barnicot, Dr. N. A., Department of Anthropology, University College London, Gower Street, London W. C. 1, England.

Barter, Mr. James T., Box 7, University Medical Center, Rochester 20, New York.

Basehart, Dr. Harry W., Department of Anthropology, University of New Mexico, Albuquerque, New Mexico.

Bass, Mr. W. M., Department of Sociology and Anthropology, University of Kansas, Lawrence, Kansas.

Bazakas, Mrs. Mary C., 2279 Jenkintown Road, Glenside, Pennsylvania.

Benton, Dr. Robert S., 1905 Alexandria Drive, Lexington, Kentucky.

Birdsell, Dr. Joseph B., Department of Anthropology and Sociology, University of California, Los Angeles 24, California.

Bleibtreu, Mr. Hermann, Peabody Museum, Harvard University, Cambridge 38, Massachusetts.

Blomquist, Dr. Harry E., Mannerheimvägen 19. A. 9, Helsingfors-Tölö, Finland.

*Bodel, Dr. John K., Hotchkiss School, Lakeville, Connecticut.

Boésen, Dr. Preben, 34 Avenue Krieg, Geneva, Switzerland.

Boyd, Dr. Lyle G., 24 Edward Street, Belmont 78, Massachusetts.

Boyd, Dr. William C., Department of Biochemistry, Boston University School of Medicine, 80 East Concord Street, Boston 18, Massachusetts.

Brace, Mr. C. Loring, Department of Sociology and Anthropology, University of Wisconsin—Milwaukee, 3203 North Downer Avenue, Milwaukee 11, Wisconsin.

Breitinger, Dr. Emil, Anthropologisches Institut der Universität Wien, Wien IX, Van Swietengasse 1, Austria.

Bresler, Dr. Jack C., Department of Biology, Brown University, Providence 12, Rhode Island.

*Briggs, Dr. L. Cabot, Hancock, New Hampshire.

Brooks, Dr. Sheilagh T., 433 Marine Place, Manhattan Beach, California.

Brožek, Dr. Josef, Department of Psychology, Lehigh University, Bethlehem, Pennsylvania.

Brues, Dr. Alice, University of Oklahoma, 801 East 13th Street, Oklahoma City 5, Oklahoma.

Buchman, Dr. Joseph, 960 Park Avenue, New York 28, New York.

Buechi, Dr. Ernest C., Rebhang 6, Schaffhausen, Switzerland.

Buettner-Janusch, Dr. John, Department of Anthropology, Yale University, New Haven, Connecticut.

Bullen, Mrs. Adelaide K., Florida State Museum, Gainesville, Florida.

Buswell, Mr. J. O., III, Department of Anthropology, Wheaton College, Wheaton, Illinois.

Campbell, Dr. Berry, Laboratory of Neurological Research, Los Angeles County Hospital, Los Angeles 33, California.

Carbonell, Dr. Virginia M., c/o Dr. K. P. Oakley, British Museum (Natural History), Cromwell Road, London S.W. 7, England.

Chandler, Dr. Kirby, Department of Anthropology, University of Washington, Seattle 5, Washington.

Chang, Dr. Shin-Yo, College of Medicine, Seoul National University, Seoul, Korea.

Chard, Dr. Chester F., Department of Anthropology, University of Wisconsin, Madison 6, Wisconsin.

---

[1] As of April 5, 1961.

Charles, Dr. Cecil M., 110 South Central Avenue, Clayton 5, Missouri.
Charney, Mr. Michael, Hackensack Biochemical Laboratory, 271 Union Street, Hackensack, New Jersey.
Chown, Dr. Bruce, 735 Notre Dame Avenue, Winnipeg 3, Canada.
Churchill, Dr. Edmund, Anthropology Section, Antioch College, Yellow Springs, Ohio.
*Cobb, Dr. W. Montague, Department of Anatomy, Howard University, Washington 1, D. C.
Cole, Mr. Glen H., Department of Anthropology, University of Chicago, 1126 East 59th Street, Chicago 37, Illinois.
Collins, Dr. Henry B., Jr., Smithsonian Institution, Washington 25, D. C.
Comas, Dr. Juan, Alberto Zamora 69, Coyoacan, D.F., Mexico.
Coolidge, Mr. Harold J., Jr., 3005 O Street, N. W., Washington 7, D. C.
Coon, Dr. Carleton S., University Museum, University of Pennsylvania, Philadelphia 4, Pennsylvania.
Cornwell, Mr. William S., 350 Westminster Road, Rochester 7, New York.
Cosentino, Mr. John A., 15 Wellesley Road, Upper Montclair, New Jersey.
Count, Dr. Earl W., Anthropology Department, Hamilton College, Clinton, New York.
Craven, Dr. A. H., East Lansing Medical Center Building, East Grand River, East Lansing, Michigan.
Cressman, Dr. L. S., Department of Anthropology, University of Oregon, Eugene, Oregon.
Cureton, Dr. Thomas Kirk, 213 Huff Gymnasium, University of Illinois, Urbana, Illinois.
Dahlberg, Dr. Albert A., 5756 Harper Avenue, Chicago 37, Illinois.
Damon, Dr. Albert, Harvard School of Public Health, 1 Shattuck Street, Boston 15, Massachusetts.
Damon, Dr. Selma Thomsen, 98 Homer Street, Newton Centre 59, Massachusetts.
*Danforth, Dr. C. H., Department of Anatomy, Stanford University, California.
Dawson, Dr. Helen L., College of Medicine, State University of Iowa, Iowa City, Iowa.
*Deignan, Dr. Stella Leche, 2120 Bancroft Place, N.W., Washington 8, D. C.
del Boca di Villaregia, Count Bernardino, Via Zuretti 2, Milano 509, Italy.
Dempster, Dr. W. T., Department of Anatomy, University of Michigan School of Medicine, Ann Arbor, Michigan.
DePalma, Dr. Anthony F., 248 South 21st Street, Philadelphia 3, Pennsylvania.
de Diaz Ungria, Dr. A. G., Quinta Magerit, Av. Este, Alta Florida, Caracas, Venezuela.
De Vore, Mr. Irven, Department of Anthropology, University of California, Berkeley 4, California.
Dobzhansky, Dr. Th., Department of Zoology, Columbia University, New York 27, New York.
Du Brul, Dr. E. Lloyd, College of Dentistry, University of Illinois, 808 South Wood Street, Chicago 12, Illinois.
Duggins, Dr. Oliver H., Jr., 10 Alden Lane, Creve Coeur 41, Missouri.
Duncan, Dr. Donald, 114 Tarpon, Galveston, Texas.
Dunn, Dr. L. C., Department of Zoology, Columbia University, New York 27, New York.
Dupertius, Dr. C. Wesley, Western Reserve University, School of Medicine, Cleveland 6, Ohio.
Dyson, Mr. Robert H., Jr., University Museum, 34th and Spruce Streets, Philadelphia 4, Pennsylvania.
Eads, Dr. William F., 1651 Garnet Street, San Diego 9, California.
Ehrich, Dr. Robert W., Department of Sociology and Anthropology, Brooklyn College, Brooklyn, 10, New York.
Eiseley, Dr. Loren C., Anthropology Department, University of Pennsylvania, Philadelphia 4, Pennsylvania.
Elliot, Mr. Orville S., Department of Anthropology, Harvard University, Cambridge 38, Massachusetts.
Ericksen, Mrs. Mary Frances, U. S. Geological Survey, Foreign Branch, Washington 25, D. C.
Erikson, Dr. G. E., Harvard Medical School, Boston 15, Massachusetts.
Estel, Dr. Leo A., Anthropology Department, Ohio State University, Columbus 10, Ohio.
Evans, Dr. F. G., Department of Anatomy, School of Medicine, University of Michigan, Ann Arbor, Michigan.
Eveleth, Mrs. Phyllis B., c/o First National City Bank of New York, Caixa Postal 770, Rio de Janeiro, Brasil.
Ewing, Rev. J. F., S.J., Fordham University, New York 58, New York.
Falkner, Dr. Frank, Department of Pediatrics, University of Louisville School of Medicine, Louisville 2, Kentucky.
Fanning, Dr. Elizabeth A., Forsyth Dental Infirmary, 140 Fenway, Boston 15, Massachusetts.
Fejos, Dr. Paul, Wenner-Gren Foundation, 14 East 71st Street, New York 21, New York.
Field, Dr. Henry, 3551 Main Highway, Coconut Grove, Miami 33, Florida.
Fleischer, Mrs. Helen J., Box 9949, Santurce, Puerto Rico.
*Fortuyn, Dr. A. B. D., Julianalaan 19, Oegstgeest, Holland.
Frisch, Rev. John E., S.J., St. Bernard's School of Nursing, 6344 South Harvard Avenue, Chicago 21, Illinois.
Fry, Dr. Edward I., Department of Anthropology, University of Nebraska, Lincoln 8, Nebraska.
†Gabel, Dr. Norman E., Department of Sociology and Anthropology, University of California, Santa Barbara, Goleta, California.
Garn, Dr. Stanley M., Fels Research Institute, Yellow Springs, Ohio.
Gavan, Mr. James A., Department of Anatomy, South Carolina Medical College, Charleston, South Carolina.
Gejvall, Dr. Nils-Gustav, Academy of History and Antiquities, 41 Storgatan, Stockholm Ö, Sweden.
Genovés, Dr. Santiago Carlos, Instituto de Historia, Torre de Humanidades, Cuidad Universitaria, México 20, D. F., Mexico.
Gertler, Dr. Menard M., 1000 Park Avenue, New York 21, New York.
Giles, Mr. Eugene, Department of Anthropology, Harvard University, Cambridge 38, Massachusetts.

Gillette, Dr. Charles E., Curator of Archeology, New York State Museum, Albany 1, New York.

Gillin, Dr. John P., Dean Division of Social Sciences, University of Pittsburgh, Pittsburgh 13, Pennsylvania.

Givens, Mr. R. Dale, Department of Anthropology, University of Texas, Austin 12, Texas.

Glass, Dr. Bentley, Department of Biology, Johns Hopkins University, Baltimore 18, Maryland.

Godfrey, Dr. William, Jr., Beloit College, Beloit, Wisconsin.

Goff, Dr. C. W., 30 Farmington Avenue, Hartford, Connecticut.

Goldstein, Dr. Marcus, U. S. Public Health Service, Washington 25, D. C.

Gosman, Dr. S. D., 2 South Frontenac Avenue, Margate City, New Jersey.

Goss, Dr. Charles M., Anatomy Department, Louisiana State University School of Medicine, New Orleans 12, Louisiana.

*Gower, Professor Charlotte D. (address unknown).

Grant, Dr. J. C. B., Department of Anatomy, University of Toronto, Toronto 5, Canada.

Gray, Dr. Donald J., Anatomy Department, Stanford University, California.

Gray, Miss Margery P., Department of Medicine, University of Wisconsin Medical School, Madison 6, Wisconsin.

Greene, Dr. Theodore C., Department of Anatomy, Meharry Medical College, Nashville 8, Tennessee

Greulich, Dr. William Walter, P. O. Box 2989, Stanford, California.

Gruber, Dr. Jacob W., Department of Sociology and Anthropology, Temple University, Philadelphia 22, Pennsylvania.

Guttentag, Dr. Otto E., University of California School of Medicine, The Medical Center, San Francisco 22, California.

Guze, Dr. Henry, 299 Clinton Avenue, Newark 8, New Jersey.

Halloran, Mr. Arthur F., Wildlife Management Biologist, Wichita Mountains Refuge, Cache, Oklahoma.

Hamilton, Dr. James B., State University of New York, Business Office, Downstate Medical Center, 450 Clarkson Avenue, Brooklyn 3, New York.

Hamlin, Dr. Hannibal, 270 Benefit Street, Providence 3, Rhode Island.

Hammerstrom, Mr. Carl, 733 North Broadway, Baltimore 5, Maryland.

Handy, Dr. E. S. C., P. O. Box 57, Oakton, Virginia.

Hanihara, Dr. Kazuro, Department of Legal Medicine, Sapporo Medical College, Nishi 17, Minami 1, Sapporo, Hokkaido, Japan.

Hanna, Dr. Bertram L., National Institutes of Health, Bethesda 14, Maryland.

Hartle, Mrs. Janet Arcuni, 5506 Greentree Road, Bethesda 14, Maryland.

Haskell, Miss Joan Adams, Anthropology Section, Antioch College, Yellow Springs, Ohio.

Heglar, Mr. Rodger, Laboratory of Physical Anthropology, University of Michigan, 1133 East Catherine, Ann Arbor, Michigan.

Henderson, Mr. Gerald, Department of Sociology and Anthropology, Brooklyn College, Brooklyn 10, New York.

Herndon, Dr. C. N., Department of Medical Genetics, Bowman Gray School of Medicine, Winston-Salem, North Carolina.

Herskovits, Dr. Melville J., Northwestern University, College of Liberal Arts, Evanston, Illinois.

Hertzberg, Mr. H. T. E., 414 North Park Place, Yellow Springs, Ohio.

Heuse, Dr. Georges A., 167 Rue de Rennes, Paris 6, France.

Hjortsjö, Dr. Carl-Herman, Anatomical Institution at the University of Lund, Biskopsgatan 7, Lund, Sweden.

Holcomb, Dr. George R., Department of Anatomy, School of Medicine, University of North Carolina, Chapel Hill, North Carolina.

Hooijer, Dr. D. A., Rijksmuseum van Natuurlijke Historie, Leiden, Netherlands.

Howell, Dr. F. Clark, Department of Anthropology, University of Chicago, Chicago 37, Illinois.

Howells, Dr. W. W., Peabody Museum, Harvard University, Cambridge 38, Massachusetts.

Howorth, Dr. M. Beckett, 1 Atlantic Street, Stamford, Connecticut.

Hoyme, Miss Lucile E., Division of Physical Anthropology, U. S. National Museum, Washington 25, D. C.

*Hughes, Dr. Byron O. (address unknown).

Hulse, Dr. Frederick S., Department of Anthropology, University of Arizona, Tucson, Arizona.

Hunt, Dr. Edward E., Forsyth Dental Infirmary, 140 The Fenway, Boston 15, Massachusetts.

Hunt, Mrs. Vilma Rose, Forsyth Dental Infirmary, 140 The Fenway, Boston 15, Massachusetts.

Hurme, Dr. V. O., 61 Main Street, Plymouth, New Hampshire.

Jaén, Miss Maria Teresa, Ernesto Elorduy 12, Colonia Guadalupe Inn, Mexico 20, D. F.

Jay, Mrs. Phyllis J., Department of Anthropology, University of California, Berkeley, California.

Jensen, Dr. Dorothy C., Department of Anthropology, Hunter College, 695 Park Avenue, New York 21, New York.

Johnston, Mr. Francis E., Philadelphia Center for Research in Child Growth, 1701½ Fitzwater Street, Philadelphia 46, Pennsylvania.

Jones, Mrs. Bonnie M., 29 Edgehill Road, Birmingham 9, Alabama.

*deJonge, Dr. Th. E., Anatomisch-Embryologisch Laboratorium, Universiteit van Amsterdam, Mauritskade 61, Amsterdam-oost, Holland.

Jørgensen, Dr. Jorgen Balslev, Universitetets Anthropologiske Lab., Norrealle 63, Copenhagen, Denmark.

Kaplan, Dr. Bernice, c/o Dr. G. W. Lasker, 1401 Rivard Street, Detroit 7, Michigan.

Kaplan, Dr. E. B., 1001 Grand Concourse, New York 52, New York.

Karvonen, Dr. Martti J., Institute of Occupational Health, University of Helsinki, Helsinki, Finland.

Keiter, Dr. Friedrich, Breitenfelderstrasse 62, Hamburg 20, Germany.

Kelso, Dr. Jack, Department of Anthropology, University of Colorado, Boulder, Colorado.

Kerley, Mr. Ellis R., AFIP, Room 245, 6825 16th Street, N.W., Washington 25, D. C.

Keur, Dr. Dorothy L., 2475 Palisade Avenue, New York 63, New York.

King, Dr. Arden R., Middle American Research Institute, Tulane University, New Orleans 18, Louisiana.

Kinzey, Mr. Warren, Department of Anthropology, University of Chicago, Chicago 37, Illinois.

Klatsky, Dr. Meyer, 520 Montgomery Street, Brooklyn 25, New York.

†Kluckhohn, Dr. Clyde, Peabody Museum, Cambridge 38, Massachusetts.

Koski, Dr. Kalevi, Department of Anatomy, University of Turku, Turku 3, Finland.

Krahl, Dr. Vernon E., University of Maryland, 29 South Greene Street, Baltimore 1, Maryland.

Kraus, Dr. Bertram S., Department of Orthodontics, School of Dentistry, University of Washington, Seattle 5, Washington.

Krause, Miss Gretchen R., 1532 Cardiff Road, Columbus 21, Ohio.

Krogman, Dr. W. M., Philadelphia Center for Research in Child Growth, 1701½ Fitzwater Street, Philadelphia 46, Pennsylvania.

Kropp, Dr. Benjamin N., Department of Histology and Embryology, Queen's University, Kingston, Ontario, Canada.

Lachman, Dr. Ernest, University of Oklahoma, Medical School, Oklahoma City, Oklahoma.

Lapidus, Dr. Paul W., 1133 Park Avenue, New York 28, New York.

Lasker, Dr. Gabriel W., Wayne University College of Medicine, 1401 Rivard Street, Detroit 7, Michigan.

Laughlin, Dr. William S., University of Wisconsin, Department of Anthropology, Sterling Hall, Madison 6, Wisconsin.

Lay, Mr. Tracy, Department of Anthropology and Sociology, University of California at Los Angeles, Los Angeles 24, California.

Leser, Dr. Paul W., Department of Anthropology, Hartford Seminary Foundation, Hartford 5, Connecticut.

Lessa, Dr. William, Department of Anthropology and Sociology, University of California, Los Angeles 24, California.

Lesser, Dr. Ethel Boissevain, Castle Point, Hoboken, New Jersey.

Levene, Dr. Howard, Department of Mathematical Statistics, Columbia University, New York 27, New York.

Levine, Mr. Morton, Department of Anthropology, Reed College, Portland 2, Oregon.

Levine, Dr. Philip, Ortho Research Foundation, Raritan, New Jersey.

Lewis, Miss Marion, 735 Notre Dame Avenue, Winnipeg 3, Canada.

Littlewood, Dr. Robert A., Department of Sociology and Anthropology, Washington State University, Pullman, Washington.

Litvak, Mrs. Ruth Marzano, Department of Anatomy, Northwestern University, 311 East Chicago Avenue, Chicago 11, Illinois.

Livingstone, Dr. Frank B., Department of Anthropology, University of Michigan, Ann Arbor, Michigan.

Lloyd, Dr. Ruth Smith, Department of Anatomy, Howard University, Washington 1, D. C.

Longyear, Dr. John M., Department of Sociology and Anthropology, Colgate University, Hamilton, New York.

*Loo, Dr. Yu Tao (address unknown).

Loza Balsa, Mr. Gregorio, Casilla No. 643, La Paz, Bolivia.

Ludwig, Mr. Fred J., 5220 Collier Place, Woodland Hills, California.

Lusterman, Dr. E. A., 165 North Village Avenue, Rockville Centre, Long Island, New York.

Lysell, Dr. Lennart, Royal School of Dentistry, Norrlandsgatan, 18B, Umeå 1, Sweden.

Machado de Souza, Professor Odorico, Universidada de São Paulo, Faculty of Medicine, Rua Helvetia 55, Caixa Postal 8191, São Paulo, Brazil.

Mack, Dr. Pauline B., Dean, College of Household Arts and Sciences, Texas Woman's University, Denton, Texas.

Mackal, Dr. Roy Paul, Department of Biochemistry, University of Chicago, Chicago 37, Illinois.

Marshall, Dr. Donald S., Far Lands House, 1 Braman Street, Danvers, Massachusetts.

Matson, Dr. G. A., Minneapolis War Memorial Blood Bank, 2304 Park Avenue, Minneapolis 4, Minnesota.

Mayr, Dr. Ernst, Museum of Comparative Zoology, Harvard University, Cambridge 38, Massachusetts.

McConville, Mr. John T., Anthropology Section, Antioch College, Yellow Springs, Ohio.

McCown, Mrs. Elizabeth R., 1114 Oxford Street, Berkeley 7, California.

McCown, Dr. Theodore D., Department of Anthropology, University of California, Berkeley 4, California.

McFarland, Dr. Ross A., Department of Industrial Hygiene, Harvard School of Public Health, 1 Shattuck Street, Boston 15, Massachusetts.

McGregor, Dr. John C., 137D Davenport Hall, University of Illinois, Urbana, Illinois.

McKern, Dr. Thomas W., Department of Anthropology, University of Texas, Austin 12, Texas.

Mednick, Mrs. Lois Wells, 5012 South Dorchester Avenue, Chicago 15, Illinois.

Menegaz-Bock, Mrs. Renée M., Department of Anatomy, University of North Carolina Medical School, Chapel Hill, North Carolina.

Meredith, Dr. Howard V., Iowa Child Welfare Research Station, State University of Iowa, Iowa City, Iowa.

Michelson, Dr. Nicholas, Veterans Administration, Box 134, Lyons, New Jersey.

Miles, Miss Meryl, Bardeen Medical Laboratories, Madison 6, Wisconsin.

Milgram, Dr. Joseph, Hospital of Joint Diseases, 1919 Madison Avenue, New York 35, New York.

*Mills, Dr. C. A. (address unknown).

Mitchell, Dr. Matthew, 1238 H Street, N.E., Washington 2, D. C.

Montagna, Dr. William, Department of Biology, Brown University, Providence 12, Rhode Island.

Montagu, Dr. M. F. Ashley, Cherry Hill Road, Princeton, New Jersey.

Moody, Dr. Paul A., Department of Zoology, University of Vermont, Burlington, Vermont.

Moorrees, Dr. Coenraad F. A., Forsyth Dental Infirmary, 140 The Fenway, Boston 15, Massachusetts.

Morris, Mr. Donald Harvey, 3301 East Earll Drive, Phoenix 18, Arizona.

Moss, Dr. Melvin L., Anatomy Department, Columbia University, 630 West 168th Street, New York 32, New York.

Murrill, Dr. Rupert, Department of Anthropology, University of Minnesota, Minneapolis 14, Minnesota.

Neumann, Dr. G. K., Department of Anthropology, Indiana University, Bloomington, Indiana.

Neumann, Mr. Holm W., 704 South Rose Avenue, Bloomington, Indiana.

Newell, Miss Laura, Department of Anthropology, University of Washington, Seattle, Washington.

Newman, Dr. M. T., RR1, Box 650, Accokeek, Maryland.

Newman, Dr. Russell W., Environmental Protection Division, Quartermaster Research and Development Command, Natick, Massachusetts.

Noback, Dr. Charles R., College of Physicians and Surgeons, 630 West 168th Street, New York 32, New York.

Nussbaum, Dr. William, 82–31 Austin Street, Kew Gardens, Long Island 15, New York.

Oakley, Dr. Kenneth Page, Anthropology Section, British Museum (Natural History), Cromwell Road, London, S.W. 7, England.

O'Dell, Dr. H. W., The Akron Clinic, 513 West Market Street, Akron 3, Ohio.

Orttung, Mrs. Jane Raven, 141 Beechwood Avenue, Middlesex, New Jersey.

Osborne, Dr. Richard H., Sloan-Kettering Institute, 410 East 68th Street, New York 21, New York.

Oschinsky, Dr. Lawrence, National Museum of Canada, Ottawa, Canada.

Otten, Miss Charlotte, Department of Anthropology, University of Wisconsin, Madison, Wisconsin.

Ovenburg, Mr. Peter, Department of Zoology, Michigan State University, East Lansing, Michigan.

Paul, Dr. Benjamin D., Department of Public Health Practice, Harvard University, 55 Shattuck Street, Boston 15, Massachusetts.

Pettay, Dr. Louanna, Department of Sociology and Anthropology, Ohio State University, Columbus, Ohio.

Philippas, Dr. George G., 8 Academias Avenue, Athens, Greece.

*Phillips, Dr. T. W., 424 North Monroe Street, Media, Pennsylvania.

*Pinkely, Dr. George (address unknown).

Planansky, Dr. Karel, Veterans Administration Hospital, Canandaigua, New York.

Polacheck, Mr. Demarest, 202 Mertz Street, Midland, Michigan.

Pollitzer, Mr. William, Department of Anatomy, University of North Carolina Medical School, Chapel Hill, North Carolina.

Pope, Mrs. Betty L., 31 Elmhurst Street, Highland Park 3, Michigan.

*Post, Dr. Richard H., Quoque, Long Island, New York.

Prokopec, Dr. Miroslav, U Riegrových Sadu 6, Prague 12, Czechoslovakia.

Prost, Dr. Jack H., Department of Anthropology and Sociology, University of California at Los Angeles, Los Angeles 24, California.

Pyle, Dr. Idell, Department of Anatomy, Western Reserve University School of Medicine, 2109 Adelbert Road, Cleveland 6, Ohio.

Rabkin, Dr. Samuel, 511 Sylvan Drive, Winter Park, Florida.

Racher, Dr. Alice B., 56 Monee, Park Forest, Illinois.

Rainey, Dr. Froelich, University Museum of University of Pennsylvania, Philadelphia 4, Pennsylvania.

Ray, Dr. Leslie J., Department of Anatomy, University of Melbourne, Melbourne, Australia.

Reed, Dr. C. A., University of Illinois, College of Pharmacy, 808 South Wood Street, Chicago 12, Illinois.

Reed, Dr. Erik K., 238 Griffin Street, Santa Fe, New Mexico.

Rettig, Miss Beverly, 12801 North Road, Cleveland 11, Ohio.

Reynolds, Dr. Earle L., Phoenix Defense Fund, Honolulu, Hawaii.

Ricciardelli, Mr. Alexander, 44 Shannon Street, Middlebury, Vermont.

Riesenfeld, Mr. Alphonse, 77–10 34th Avenue, Jackson Heights, Long Island, New York.

Rife, Dr. David C., FSR New Delhi, Department of State, Washington 25, D. C.

Riley, Dr. Carroll L., Museum, Southern Illinois University, Carbondale, Illinois.

Roche, Dr. Alex F., Department of Anatomy, University of Melbourne, Melbourne, Australia.

Roche, Dr. Maurice B., 3720 Washington Boulevard, St. Louis 8, Missouri.

Romanus-Kjellgren, Dr. Torsten, Karolinska Institutet, Stockholm 60, Sweden.

Roney, Dr. James G., Jr., 426 North Main Street, Butler, Pennsylvania.

Rosenfield, Dr. Richard E., 1176 Fifth Avenue, New York 29, New York.

Rowe, Dr. Chandler W., Department of Anthropology, Lawrence College, Appleton, Wisconsin.

Salzano, Dr. Francisco M., Instituto de Ciências Naturais, Av. Paulo Gama, Pôrto Alegre, Rio Grande do Sul, Brazil.

Salzmann, Dr. J. A., 654 Madison Avenue, New York 21, New York.

Sanghvi, Dr. L. D., Indian Cancer Research Centre, Parel, Bombay 12, India.

Sarnäs, Dr. Karl V., Ryttmästargat. 26 A, Malmö V, Sweden.

Sarnat, Dr. Bernard G., 435 North Roxbury Drive, Beverly Hills, California.

Sassouni, Dr. Viken, Department of Orthodontics, West Virginia University School of Dentistry, Morgantown, West Virginia.

Saul, Mr. Frank P., Department of Anthropology, Peabody Museum, Harvard University, Cambridge 38, Massachusetts.

Saunders, Dr. J. B. deC. M., Anatomy Department, University of California, San Francisco Medical Center, San Francisco 22, California.

Schepers, Dr. G. W., E. I. DuPont de Nemours and Company, Haskell Laboratory for Toxicology and Industrial Medicine, Wilmington 98, Delaware.

Schön, Sr. Miguel A., IVIC, Apto. 1827, Caracas, Venezuela.

Schull, Dr. William J., Department of Human Genetics, University of Michigan, Ann Arbor, Michigan.

Schultz, Dr. Adolph H., Anthropologisches Institut der Universitat, Sempersteig 3, Zurich 1, Switzerland.

Scott, Professor Donald, 11 Fresh Pond Lane, Cambridge 38, Massachusetts.

Scott, Dr. J. P., R. B. Jackson Memorial Laboratory, P. O. Box 78, Bar Harbor, Maine.

Seaford, Mr. H. Wade, Department of Anthropology, Northeastern University, Boston 15, Massachusetts.

Seib, Dr. George, 2323 Lafayette Avenue, St. Louis 4, Missouri.

Selby, Dr. Samuel, Fels Research Institute, Yellow Springs, Ohio.

Seltzer, Dr. Carl C., Peabody Museum, Harvard University, Cambridge 38, Massachusetts.

Sen, Dr. Tulika, 29 Budshahag, Lucknow A. P., India.

Sensenig, Dr. E. Carl, Department of Anatomy, Medical College of Alabama, Birmingham 5, Alabama.

Senyürek, Professor Muzaffer Suleyman, Division of Paleoanthropology, Ankara Universitesi, Ankara, Turkey.

Shanklin, Dr. William M., American University, Beirut, Lebanese Republic.

Sillman, Dr. J. H., 667 Madison Avenue, New York 22, New York.

Silverman, Dr. Fred, Children's Hospital, Elland and Bethesda Avenues, Cincinnati, 29, Ohio.

Simmons, Dr. Roy T., Commonwealth Laboratories, Parkville, N. 2, Victoria, Australia.

Simons, Dr. Elwyn L., Division of Vertebrate Paleontology, Peabody Museum, Yale University, New Haven, Connecticut.

Singer, Dr. Ronald, Department of Anatomy, University of Cape Town Medical School, Mowbray, Cape, South Africa.

Skarland, Dr. Ivar, Department of Anthropology, University of Alaska, Box 11, College, Alaska.

Smith, Dr. R. Dale, Department of Anatomy, Creighton University School of Medicine, Omaha 2, Nebraska.

Snodgrasse, Dr. R. M., Temple University School of Dentistry, Broad above Allegheny Avenue, Philadelphia 40, Pennsylvania.

Snow, Dr. Charles E., Department of Anthropology, University of Kentucky, Lexington 29, Kentucky.

Snow, Mr. Clyde C., Laboratory of Primate Biology, Box 88, Humacao, Puerto Rico.

Snyder, Dr. Richard G., Anthropology Section, Protection and Survival Branch, Civil Aeromedical Research, Federal Aviation Agency, Oklahoma City, Oklahoma.

Sontag, Dr. L. W., Fels Research Institute, Yellow Springs, Ohio.

Spuhler, Dr. James N., Department of Anthropology, University of Michigan, Ann Arbor, Michigan.

Stekelis, Professor M., Hebrew University, Jerusalem, Israel.

*Stevenson, Dr. Paul H., 725 South Skinker Boule vard, St. Louis 5, Missouri.

Stewart, Dr. T. D., United States National Mu seum, Washington 25, D. C.

Straus, Dr. William L., Jr., Department of Anat omy, School of Medicine, Johns Hopkins Uni versity, Baltimore 5, Maryland.

Stucklen, Dr. Richard H., 611 North Matlac Street, West Chester, Pennsylvania.

Swindler, Dr. Daris R., Medical College of Sout Carolina, 16 Lucas Street, Charleston 16, Sout Carolina.

Tanner, Dr. J. M., Institute of Child Health, Hos pital for Sick Children, Great Ormond Street London, W. C. 1, England.

Tappen, Dr. Neil C., Division of Orthopedics Tulane Medical School, 1430 Tulane Avenue New Orleans 12, Louisiana.

Terry, Dr. Robert J., 87 Church Street, Weston 93 Massachusetts.

Thieme, Dr. Frederick P., Provost, University o Washington, Seattle, Washington.

Titiev, Dr. Mischa, 910 Heather Way, Ann Arbor Michigan.

Tobias, Dr. Phillip V., Department of Anatomy University of the Witwatersrand Medica School, Hospital Street, Johannesburg, South Africa.

Tobin, Dr. William J., 1835 Eye Street, N.W. Washington 6, D. C.

Townsley, Dr. William, 306 Shankill Road, Bel fast, Ireland.

Trotter, Dr. Mildred, Washington University Scott and Euclid Avenues, St. Louis 10, Mis souri.

Truex, Dr. R. C., Hahnemann Medical College 235 North 15th Street, Philadelphia 2, Penn sylvania.

*Tucker, Dr. William B., 106 Grafton Street Chevy Chase, Maryland.

Turner, Mr. Christy G., II, Museum of Northern Arizona, Box 402, Flagstaff, Arizona.

Vandenberg, Dr. Steven G., Louisville Twin Study Child Development Unit, Department of Pedi atrics, University of Louisville, 323 East Chest nut Street, Louisville 2, Kentucky.

Vandervael, Dr. F. A., University de Liege, Rue de Pitteurs 20, Liege, Belgium.

von Bonin, Dr. Gerhardt, 47 Upland Avenue, Mil Valley, California.

Washburn, Dr. S. L., Department of Anthropology University of California, Berkeley 4, California

Watkins, Dr. Mark Hanna, Howard University Washington 1, D. C.

Welt, Miss Carol, Department of Physiology, University of Wisconsin, Madison 6, Wisconsin.

White, Mr. Robert M., Environmental Protection Research Division, QM Research and Engineering Command, Natick, Massachusetts.

Wiener, Dr. Alexander S., 64 Rutland Road Brooklyn 25, New York.

*Williams, Dr. George D., Chief, Physical Medical Rehabilitation Service, VA Center, Martinsburg West Virginia.

*Woodbury, Dr. Robert M. (address unknown).

Wormington, Dr. H. M., Denver Museum of Natural History, City Park, Denver 6, Colorado.
†Wulsin, Dr. Frederick R., 307 Ridge Drive, Tucson, Arizona.
Young, Mr. Joseph W., 9713 Felton Avenue, Inglewood, California.
Young, Dr. Richard W., Department of Anatomy, University of California Medical Center, School of Medicine, Los Angeles 24, California.
*Zwemer, Dr. Raymond L., Assistant Science Adviser, Department of State, Washington 25, D. C.

The Skin of Primates

V. THE SKIN OF THE BLACK LEMUR (LEMUR MACACO)[1]

WILLIAM MONTAGNA, KENJIRO YASUDA AND RICHARD A. ELLIS
Arnold Biological Laboratory, Brown University, Providence, Rhode Island

A few authors have published notes on the hair and the cutaneous glands of lemurs (de Meigere, 1894; Sutton, 1887; Pocock, '18; Schwalbe, '10), but no one has studied the entire skin. In this paper we describe the skin of the black lemur, which, although somewhat resembling that of the Lorisoidea, also has many striking peculiarities.

In our studies on the comparative anatomy and the comparative histochemistry of the skin of primates, we realize that we can only survey briefly the skin of the principal genera. The skin of each animal is often enormously different, and to study each species thoroughly would require much time. We hope, therefore, that these studies will interest others who may want to follow in greater detail some of the leads presented here.

MATERIAL AND METHODS

This study is based on a single, healthy adult male, which had sired at least one normal offspring in the New York Zoological Garden. Specimens of skin from nearly all representative regions of the body were removed while the animal was in deep anesthesia.

Paraffin sections of tissues fixed in Helly's fluid and in 10% formalin were stained with hematoxylin and eosin, toluidin blue buffered to pH 4.5 (Montagna et al., '51), and the PAS technique for the demonstration of glycogen and other carbohydrates; control sections for glycogen were digested with saliva before they were treated with the PAS technique. Amylophosphorylase activity, cytochrome oxidase, monoamine oxidase, and succinic dehydrogenase activity were demonstrated in frozen sections of unfixed tissues, using respectively the methods of Takeuchi and Kuriaki ('55), Burstone ('59, '60), Glenner et al. ('57), and Farber and Louviere ('56). The following enzymes were studied in frozen sections of tissues fixed briefly in chilled 10% formalin; alkaline phosphatase (Gomori, '52); acid phosphatase (Rutenburg and Seligman, '55); nonspecific esterases (Pearse, '53); tween esterase or lipase (Stowell and Lee, '50); acetylcholinesterase and butyrylcholinesterase (Montagna and Ellis, '57). Total lipids were colored with Sudan black B, or Sudan VIII B, in frozen sections of tissues fixed in formal calcium. Cholesterol and cholesterol esters were studied in sections of tissues fixed in 80% alcohol saturated with digitonin. Some sections were observed under polarized light, others were treated with the Schultz test; both were compared with acetone-extracted controls.

GENERAL DESCRIPTION

None of the observations we have made on the living animal adds to those of Hill ('53). Our animal thrived on a varied diet of fruit, milk, cereals, and canned dog meat, supplemented with vitamins. Its only vocal expressions were guttural grunts emitted when contented, anxious, or alarmed; when handled forcibly it screamed. The animal had a rich black pelage; its only peculiarity was the color of its eyes, one of which was yellow, the other dark brown. The skin of its belly had a series of deep, parallel transverse folds; similar, but smaller folds were found on the sacral region at the base of the tail.

The pelage was woolly, with a scant population of longer guard hairs. Thick and relatively short vibrissae were found on the lips and on the supraorbital skin. Tufts

---

[1] This work was supported by grants from the United States Public Health Service (RG-2125 C11), Colgate-Palmolive Company, and Chesebrough-Pond's Inc.

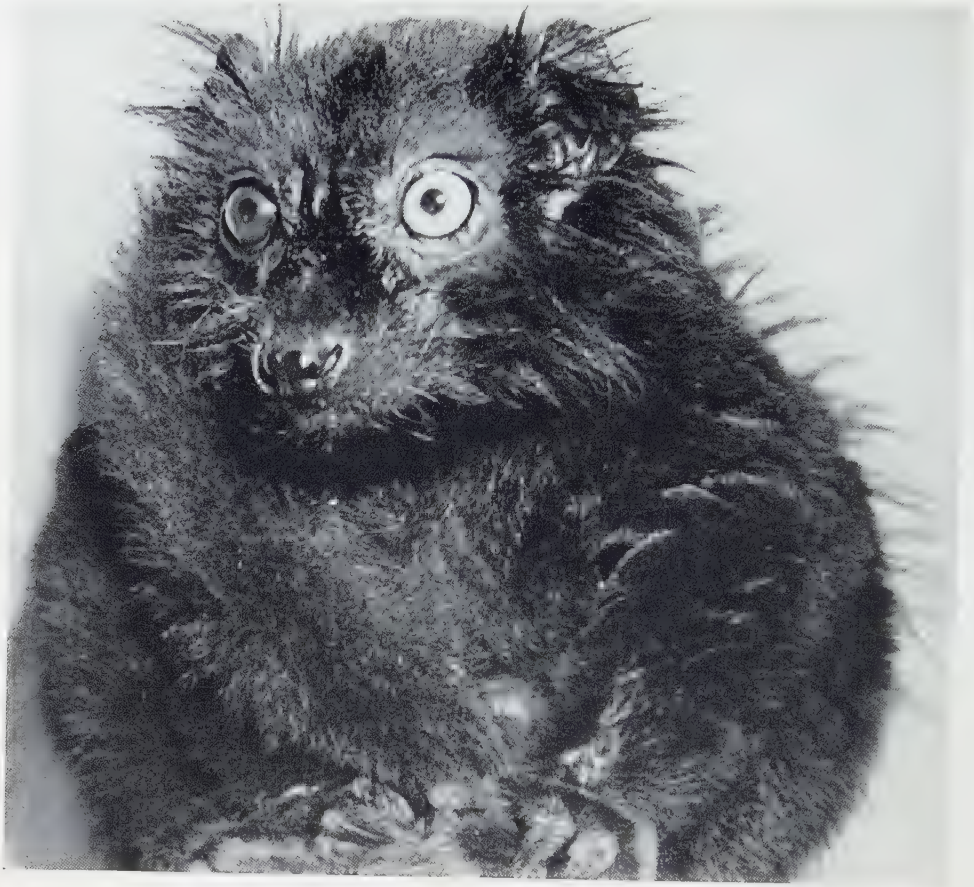


Fig. 1 Portrait of the black lemur studied in this investigation.

of longer ones grew from two cheek nevi and from a large nevus on the distal flexor surface of each forearm, proximal to the carpus (figs. 1, 2).

The epidermis

The epidermis is thickest on the muzzle and face, the carpal, scrotal, and perianal regions. All basal cells have visible cytoplasmic denticles that grow into the dermis. The spinous layer is three or more cells deep; the stratum granulosum, when present in the thicker epidermis, is usually one cell deep and discontinuous. The relatively thick stratum corneum has a compact lower portion and a flaky upper portion. The epidermis of the palms and soles is not sufficiently different from that of other primates to be described separately.

Although the skin of the clipped, intact animal was black, the epidermis contains surprisingly little pigment. A few dendritic melanocytes may be found everywhere between the basal cells, with more of them concentrated in the epidermis around the orifices of the pilary canals. The population of melanocytes is largest in the epidermis of the muzzle and face, the eyelids, the scrotum, the entire perianal skin, and the palms and soles, where even the stratum corneum contains melanin granules.

There is no glycogen in the general epidermis, except for traces in the cells of the mid-spinous layer of the epidermis around the pilary orifices. The periductal epidermal cells in the palms and soles always contain some glycogen.

A few perinuclear lipid granules, colorable with Sudan black, are found in basal and spinous cells. The stratum corneum everywhere is intensely sudanophil, even in the palms and soles.

There is practically no amylophosphorylase in the general surface epidermis; scant activity is present in the rete ridges in the palms and soles (fig. 10). The epidermis has a weak cytochrome oxidase reaction, strong succinic dehydrogenase and monoamine oxidase activity, and no alkaline phosphatase. The general body epidermis has moderate to strong acid phosphatase reaction in the spinous layer and a weak reaction in the stratum corneum; in the palms and soles, the upper portion of the spinous layer has a stronger reaction than the lower portion. The distribution of alpha naphthol esterase, naphthol AS-esterase, and tween esterase is weak to moderate in the malpighian layer and weak in the stratum corneum.

The dermis

The thick dermis has no recognizable papillary body. Only a weakly PAS-positive basement membrane separates the basal cells from the subjacent reticular layer. The dermis consists of alternating layers of longitudinally and perpendicularly arranged collagenous fibers, the longitudinal layers being thinner than the perpendicular ones. Fibroblasts are numerous throughout the dermis. Blood vessels and cutaneous appendages are almost in direct contact with the tissue of the reticular layer, there being practically no areolar tissue around them.

The hypodermal layer of white fat is thickest in the scapular and sternal regions. An extensive panniculus carnosus, well developed over the back and on the flanks, covers nearly the entire animal.

Variable numbers of bipolar and multipolar melanocytes are scattered in the dermis of the head only. Melanocytes are particularly numerous in the perivascular and perineural tissues of the eyelids, where they extend even to the ciliary muscles. They are also copious in the lips, cheeks, alae of the nose, and the nevi on the sides of the face, where they extend even to the perivascular and perineural connective tissue of the subcutaneous fat and of the facial musculature. In these regions, with the exception of mast cells, every cell in the dermis contains melanin. Every blood vessel and every nerve in the scalp, regardless of size, is surrounded by melanocytes (fig. 8). Even the periosteum and the osseous tissue of the nasal, frontal, parietal, and temporal bones contain melanocytes. The general body skin elsewhere has no obvious populations of dermal melanocytes.

The dermis contains many blood vessels, but few discernible superficial capillaries. Most of the superficial vessels have the typical large, uneven bore of veins, even in the dermal papillae of the palms and soles. The larger cutaneous vessels have some amylophosphorylase activity in their smooth muscle cells. The superficial vessels in the palms and soles have a diffuse alkaline phosphatase reaction, but nowhere is there a reactivity in the endothelium.

The pleomorphic mast cells are particularly numerous in the skin of the face, lips, and eyelids. They have metachromatically staining granules embedded in a cytoplasm that stains a homogeneous metachromatic color. Both cytoplasm and granules are weakly PAS positive.

Very few nerves in the dermis have a reaction for either specific or pseudocholinesterase. There is no dermal nerve net reactive for cholinesterase such as that found in the lorisoids (Montagna and Ellis, '60; Montagna et al., '60), and there are no cholinesterase reactive nerves around the cutaneous appendages. The very round Meissner corpuscles in the palms and soles, and the end-organs at the mucocutaneous junctions and around the genitalia both contain pseudocholinesterase, but the nerves emerging from them do not. These end-organs also contain alpha napthol esterase, but they contain none of the other enzymes that we have studied. The pacinian corpuscles contain none of these enzymes. Similarly, there are no cholinesterase-containing nerves in the skin of the scrotum, perianal region, and genitalia.

The numerous fibroblasts in the reticular layer have moderate reactions for succinic dehydrogenase, monoamine oxidase, and nonspecific esterases.

The hair follicles

Hair follicles grow in islands of 6 to 14, with some containing more (fig. 4). All of the cutaneous appendages grow within these islands, the skin between them being glabrous. Each group consists of follicles of guard hairs, usually active, and follicles of wool, or underhair, usually quiescent. The ratio of wool follicles to guard hair follicles is about 3 or 4 to one; on the scalp it is about two to one. The orifices of all the follicles in a single island open into a shallow depression on the surface of the skin, similar in arrangement to that in the skin of the potto (Montagna and Ellis, '59), and the chinchilla (Wilcox, '50). The ducts of the sebaceous glands and those of the sweat glands open directly to the surface between the orifices of the pilary canals.

All hairs have a large medulla, broken at intervals by air spaces, like those of the lorisidae. Both cortex and medulla are heavily pigmented. The hairs in quiescent hair follicles have a club that is free of pigment, as is also the thinner, nonmedullated hair shaft that extends from the club to the surface of the skin. Quiescent follicles are less than one-third the length of active ones, and each contains only one acuminate club hair. The clubs, therefore, are cast off when the follicles become active.

The follicles resemble those of other lemuroids, but they have singular peculiarities. None of the follicles, except those of the vibrissae, has sebaceous glands, and none of the follicles, except those of the tail, has well developed arrectores pilorum muscles. Hair follicles are rich in pigment. Active ones have melanocytes in the outer root sheath, all through the upper part of the bulb, and even in the dermal papilla. Quiescent follicles have pigment in the pilary canal, the epithelial capsule around the hair club, the hair germ, and the dermal papilla. Other than these differences, the general histological and histochemical attributes of the hair follicles are similar to those of the lorisoids (Montagna and Ellis, '59, '60; Montagna et al., '60).

The distribution of glycogen in active follicles resembles that in the follicles of other primates. In quiescent follicles it is concentrated in the cells of the epithelia capsule.

In active follicles, amylophosphorylase activity extends from the bottom of the pilary canal to the upper part of the bulb where it disappears abruptly. In quiescent follicles, intense enzyme activity is limited to the cells of the epithelial capsule around the hair club. Only the dermal papilla of either active or quiescent follicles shows alkaline phosphatase; none of the blood vessels around them shows a reaction. There are no nerves around the hair follicles that have a reaction for cholinesterases; even the nerves around the sinus hair follicles show no reaction. The distribution of the other enzymes we have studied is like that reported in the hair follicles of other primates.

One of the peculiar external features of the black lemur is the tuft of stiff bristles growing over a darkly pigmented nevus on the flexor side of the forearm (figs 1, 2). Sutton (1887) described tufts of hair surrounded by many glands on the carpal region of *Lemur catta*, and assumed that *Lemur macaco* also possessed such glandular accumulation. Actually, these hairs are vibrissae that grow from typical sinus hair follicles (Pocock, '18; Hill, '53), with no glands around them (fig. 3).

The sebaceous glands

The sebaceous glands of the black lemur have several unique features. Large and numerous everywhere, they are largest in the scalp (fig. 5), the scrotum (fig. 6), and the entire perianal region, where, deep in the dermis, they crowd out the other cutaneous appendages. There are two morphologically distinct sebaceous glands. Over most of the body skin the glands have a single, balloon-like, round or oval acinus with a duct that extends from the center of the acinus to the surface. The duct opens directly to the surface near, but *not* inside a pilary canal. The terminal segment of the duct is tortuous and occasionally helical; the lumen, often festooned with epithelial folds, is packed with dark brown or black sebum (figs. 5, 6, 8). This color begins abruptly in the center of the gland and does not develop gradually from the periphery. Sebaceous degeneration in the center of the acini is slow and breakdown of mature sebaceous cells is not conspicuous. Intact, but mature, cells are often found near the periphery of the acini, and a single layer of flattened undifferentiated cells surrounds each acinus. Scattered between sebaceous cells are dendritic melanocytes, and each sebaceous cell contains some melanin granules. Delicate dendritic melanocytes are also found between the cells of the duct, particularly in the basal portion. The duct is fairly straight, its lumen is often tortuous, and is about two layers of cells thick (figs. 5, 6, 8).

A second type of sebaceous gland resembles the glands in other mammals. These are large and have several acini, the ducts of which converge toward one large excretory duct that opens directly onto the surface of the skin (fig. 7). The sebaceous cells undergo a progressive maturation from the periphery to the center of the acini, as those in the glands of other mammals do. The acini contain visible decaying cells and abundant sebum. There are no melanocytes between the sebaceous cells and the sebum is never brown or black. This more typical sebaceous gland is found only in the skin of the lips, the face, the scrotum, and the perianal region.

The sebaceous glands of sinus hair follicles open into the pilary canal and constitute a third type of gland similar to those of other mammals.

When colored with Sudan black, the sequence of sebaceous maturation can be traced much more clearly in the multiple acinar glands than in the single acinar ones. In the single acinar glands nearly all of their cells may be laden with lipid, although none may be undergoing decay. The sebum, whether pigmented or not, is always deeply sudanophilic.

None of the sebaceous glands over the general body surface contains glycogen. The differentiating peripheral cells in the glands of the perianal region and the scrotum, however, have a small amount of glycogen. The ducts of the uniacinar glands have a trace of glycogen only in the deeper portion. The ducts of the multiacinar glands often have glycogen.

There is some amylophosphorylase activity only at the periphery of the acini of the glands in the scrotum and in the perianal region. The ducts of these glands also have some enzyme activity. The uniacinar glands have amylophosphorylase only in the deeper portion of the duct.

All glands have a moderate acid phosphatase activity, more intense in the multilobulated glands of the scrotum and perianal region than in the uniacinar glands elsewhere. The ducts have a greater concentration of enzyme than the glands do. The peripheral cells in all sebaceous glands have intense cytochrome oxidase, succinic dehydrogenase and monoamine oxidase activities; the center of the acini has scant or no reaction and the ducts have a weak to moderate reaction.

The alpha naphthol esterase reaction is moderate to strong in the periphery of the acini of the single acinar glands and their ducts; the center of the acini shows practically no reaction. The multilobulated glands have a weaker reaction. The distribution of AS naphthol esterase in the uniacinar glands is essentially the same as that of alpha napthol esterase. The multilobulated glands have a stronger AS esterase reaction throughout the acini and even the sebum is intensely reactive. All sebaceous glands exhibit tween esterase activity at the periphery of the acini; the center of the acini and the sebum have practically no activity and the sebum is negative. None of the glands, not even the meibomian glands, is surrounded by cholinesterase-containing nerves.

Only a few of the mature cells in the uniacinar glands over the general body surface have some alkaline phosphatase reaction; the peripheral cells have none. In the multiacinar glands of the lips, the cells undergoing sebaceous transformation have abundant alkaline phosphatase, but in the large, multiacinar glands in the scrotum and perianal region, all of the acini have intense enzyme activity (fig. 7). None of the sebaceous glands is surrounded by capillaries lined with a phosphatase-rich endothelium.

The sweat glands on the general body surface

Only one sweat gland, apparently apocrine, is associated with each hair group (fig. 5). The glands are different over the various regions of the body. The dilated, slightly coiled, simple tubular glands open to the surface of the skin through a long, very narrow duct (fig. 5). The terminal segment of the duct near its orifice is cone-shaped, and its lumen is thrown into folds. The diameter of the terminal part of the duct is relatively large; it is very narrow as it traverses the dermis and again dilated, and with a tortuous lumen, before it joins the secretory coil. The duct consists of two or three layers of flat cuboidal cells, the luminal ones having a slight cuticular free edge. The secretory cells commence abruptly; they are columnar or cuboidal, depending upon the state of dilation of the tubule. The free cytoplasmic border of the same secretory cells may occasionally protrude into the lumen. The cytoplasm of the apocrine cells contains variable quantities of perinuclear yellow or orange pigmented granules. The cytoplasm stains a homogeneous basophil color around the nucleus, but has a dense stippling of basophil granules above it.

The apical cytoplasm often stains a slight metachromatic color with toluidin blue. The lumen of some glands contains clear or flocculent materials which stain metachromatically. The myoepithelial cells that surround the secretory segment are very small.

Apocrine glands are more numerous and apparently more active in the skin of the face and lips. They are larger still in the skin of the scrotum and in that of the perianal region, where they are intermingled with the large sebaceous glands.

The granules in the cytoplasm, pigmented or not, are PAS-reactive (fig. 9). The cells also contain diffuse small amounts of glycogen. The glands have no conspicuous sudanophil substances. The cells are moderately reactive for cytochrome oxidase and are rich in succinic dehydrogenase and monoamine oxidase; the ducts have only traces of these enzymes. The ducts have appreciable amounts of amylophosphorylase, but the secretory epithelium has none. The apical portion of the secretory cells and the luminal cells in the duct have alkaline phosphatase activity. No blood vessels with a phosphatase-rich endothelium surround the glands. The secretory cells have a moderate to weak acid phosphatase reaction, but the cells of the duct have none. The secretory segment of the glands on the scrotum and face have a strong alpha naphthol esterase reaction; those elsewhere have a less intense activity; the duct is never reactive. The glands of the lips, scrotum, and perianal regions have a strong naphthol AS acetate esterase reaction; those elsewhere have a weaker reaction. The ducts show no enzyme. The distribution of tween esterase is identical with that of AS esterase. There are no cholinesterases in the epithelial cells of the glands and no cholinesterase-containing nerves around the glands.

The glands of the volar surfaces of the hands and feet

Sweat glands are most numerous in the ball of the fingers. They are slightly convoluted glands and rest deep in the fatty pad. The intraepidermal portion of the duct of the glands is tightly coiled. Although the intraepidermal part of the duct is non-pigmented, the part that traverses the dermis contains small melanocytes along nearly its entire length. The transition between the duct and the secretory segment is abrupt. The duct is composed of two layers of low cuboidal cells, those near the surface being partially hyalinized.

The single row of secretory cells is so crowded that it simulates a double row of small and large cuboidal or pyriform cells; all of the cells, however, are of one type. Stained with toluidin blue, the cells have a slightly basophil cytoplasm with fine metachromatic granules in the supranuclear mass. Two or more coarse, yellow pigment granules near the nucleus stain a greenish color with toluidin blue. The deeply basophil, round nuclei have one or more nucleoli. Clefts between the cells outline simple intercellular canaliculi. The myoepithelial cells around the epithelial cells are very large.

The duct, except for traces in the basal cells, is free of glycogen. The secretory cells contain three PAS-positive elements: (a) some glycogen, diffusely distributed in the cytoplasm, often piled up against the walls of the intercellular canaliculi; (b) pigmented granules strongly PAS-positive even after digestion with saliva; (c) numerous PAS-positive, nonglycogen granules crowded in the supranuclear cytoplasm, and even free with the lumen. The basement membrane has a thin, intensely PAS-positive inner layer that follows every contour of the myoepithelial cells and an outer, thick, hyalin, probably collagenic layer, that is only slightly PAS-reactive.

A diffuse sudanophilia at the apices of the secretory cells represents the only demonstrable lipid substance.

The entire gland is reactive for amylophosphorylase (fig. 10). Cytochrome oxidase, succinic dehydrogenase, and monoamine oxidase show strong activity in the secretory coil but little or none in the duct.

Alkaline phosphatase is localized only in the intercellular canaliculi of the gland (fig. 11). A few, very slightly reactive capillaries can sometimes be found near the secretory coils. The glands have moderate to strong acid phosphatase activity. Alpha naphthol esterase activity is particularly strong in the secretory cells and in the intraepidermal portion of the duct. AS naphthol esterase is weakly distributed throughout the gland. The secretory coil has a conspicuous concentration of tween esterase. The basal part of the secretory cells and the myoepithelial cells give a strong acetyl and butyrylcholinesterase reaction. There are no nerves reactive for cholinesterase around the coils of the glands.

DISCUSSION

The skin of the black lemur has many peculiarities, and is distinctly different from the skin of the other mammals we have studied.

All cutaneous appendages are found within the confines of islands of hair follicles as in the skin of the lorisoids. These islands, then, are the foci from which hair follicles, sebaceous glands, and sweat glands develop. Such intimate association of all cutaneous appendages suggests that they may have a common origin and that the skin of the lemur could be considered to be primitive.

The arrangement of hair follicles is largely like that found in the lorisoids. In an attempt to relate the growth of hair follicles to that of ancestral scales, de Meijere (1894) described the follicles of the lemur growing in groups of three. He erred, however, since follicles grow in large groups or islands, always including some guard hairs and variable numbers of wool hairs. A grouping of follicles in large clusters of inconstant numbers seem to be a generalized feature.

The hair follicles of the black lemur have two striking peculiarities; most of them have no arrectores pilorum muscles, and with the exception of sinus follicles, they are all free of sebaceous glands. It remains to be seen if these, as well as other idiosyncrasies described herein, are also found in the skin of other Lemuridae.

The most striking departure from the usual condition in the skin of other mammals is in the sebaceous glands. The two types of glands, single acinar and multiple acinar, are found in separate sites, the multiacinar ones being on the face and lips, the scrotum, and the perianal region, the single acinar ones everywhere else. The single acinar glands have long tortuous ducts that open to the surface near the pilary canals. The presence of melanocytes between the sebaceous cells, pigment granules inside the sebaceous cells, and the black or brown color of the sebum make the glands enormously interesting. The color of the sebum is not extracted with organic solvents; it is bleached by 10% hydrogen peroxide, is stained a deep blue with the ferric ferrocyanide reduction test (Lillie, '54), and may contain melanin. Yet, there are not enough melanocytes to account for such intense pigmentation and there is no gradual increase in the intensity of the coloration in the sebum from the periphery to the center of the acinus. Actually, the mature sebaceous cells, before they break down, have only a few pigment granules. Thus, in spite of the apparent presence of melanin, the pigment must be largely something else. The multilobulated sebaceous glands have neither melanocytes in the acini nor pigment in the sebum. There are several histochemical differences between the two types of sebaceous glands; of these none is more interesting than the presence of glycogen only in the multilobulated glands. These glands, then, resemble more the types found in other primates, whereas the single acinar ones seem to be peculiar to the black lemur.

The sweat glands are not well differentiated. Those over the general body surface are apocrine, but some of their histochemical properties are like those of eccrine glands. The glands in the palms, soles, and digits are evidently eccrine, but they resemble both eccrine and apocrine glands. The cells are all of one type and are separated by simple intercellular canaliculi. Neither the apocrine glands of the general body surface nor the questionable eccrine glands of the palms and soles is surrounded by nerves that contain cholinesterase. Those of the palms and soles contain cholinesterase in the myoepithelial cells, like the glands in the digital pads of the dog (Hellmann, '55) and of the raccoon (personal observations).

Since all sweat glands resemble both eccrine and apocrine types, neither type of gland has deviated appreciably from a hypothetical generalized type. This belief is strengthened by the rudimentary pharmacological observations we have made. The glands of the palms and soles sweat when either adrenalin or mecholyl is injected intradermally, the refractory period being longer after the injection of adrenalin. The glands of the general body surface, particularly where they are largest and most numerous (face, scrotum, and perianal region), respond weakly only to adrenalin. If a tentative conclusion can be drawn from this and from the studies of the lorisoidea (Montagna and Ellis, '59, '60; Montagna et al., '60), both eccrine and apocrine glands may have evolved from a single stem gland, which perhaps, morphologically, resembled the apocrine glands.

The dermis has practically no papillary body. The cutaneous appendages and the blood vessels are almost in contact with the reticular layer, there being very little areolar tissue around them. As if to compensate for this, the reticular layer is unusually rich in fibroblasts. A peculiarity of the dermis of the head is the presence of large numbers of melanocytes in the perivascular and perineural tissue. In places melanocytes are so numerous that they even invade the periosteum of the dermal bones and the muscular tissues. This is particularly remarkable since elsewhere the dermis is free of melanocytes.

The various details of this study emphasize at the same time an apparent primitiveness and an apparent specialization of the skin of the lemur. A study of other Lemuridae will indubitably throw some light upon some of these paradoxes.

SUMMARY

1. The skin of the black lemur, while having similarities to that of the lorisoids, has several distinct idiosyncracies.

2. The dermis has practically no papillary body, and the cutaneous appendages are apparently poorly vascularized. The dermis of the skin of the head, but not that of the skin elsewhere, contains variably numerous melanocytes.

3. The hair follicles grow in large clusters of variable numbers. Hair follicles are singular in that they abound in pigment, even in the outer root sheath; they have no arrectores pilorum muscles and no sebaceous glands opening into the pilary canal.

4. The sebaceous glands, except those associated with sinus hair follicles, open directly to the surface. Two types of glands are present: (a) those of the general body surface, which consist of a single acinus that opens to the surface by way of a long, narrow duct, and (b) those of the face, scrotum, and perianal region which are multiacinar.

5. The sweat glands over the general body surface are apocrine and poorly developed; those on the palms and soles are eccrine. Both types of glands are very simple and probably represent primitive types.

6. The various cutaneous appendages have characteristic histochemical properties, only some of which are similar to those of the appendages of lorisoids.

LITERATURE CITED

Burstone, M. S. 1959 New histochemical technique for the demonstration of tissue oxidase (*cytochrome oxidase*). J. Histochem. Cytochem., *7:* 112–122.

——— 1960 Histochemical demonstration of cytochrome oxidase with new amine reagents. Ibid., *7:* 63–70.

de Meijere, J. C. H. 1894 Über die Haare der Säugetiere besonders über ihre Anordnung. Gegenbaur's Morph. Jahrb., *21:* 312–424.

Farber, E., and C. D. Louviere 1956 Histochemical localization of specific oxidative enzymes. IV. Soluble oxidation-reduction dyes as aids in the histochemical localization of oxidative enzymes with tetrazolium salts. J. Histochem. Cytochem., *4:* 347–356.

Glenner, G. G., H. J. Burtner and G. W. Brown, Jr. 1957 The histochemical demonstration of monoamine oxidase activity by tetrazolium salts. Ibid., *5:* 591–600.

Gomori, G. 1952 Microscopic Histochemistry. Principles and Practice. The University of Chicago Press, Chicago, Illinois.

Hellmann, K. 1955 Cholinesterase and amine oxidase in the skin: A histochemical investigation. J. Physiol., *129:* 454–463.

Hill, W. C. O. 1953 Primates, Comparative Anatomy and Taxonomy. I. Strepsirhini. Interscience Publishers, New York, pp. 270–272. Edinburgh at the University Press.

Lillie, R. D. 1954 Histopathologic Technic and Practical Histochemistry. The Blakiston Company, Inc., New York.

Montagna, W., H. B. Chase and J. B. Hamilton 1951 The distribution of glycogen and lipids in human skin. J. Invest. Dermatol., *17:* 147–157.

Montagna, W., and R. A. Ellis 1957 Histology and cytochemistry of human skin. XII. Cholinesterases in the hair follicles of the scalp. Ibid., *29:* 151–157.

Montagna, W., R. A. Ellis 1959 The skin of primates. I. The skin of the potto (*Perodicticus potto*). Am. J. Phys. Anthrop., *17:* 137–162.

——— 1960 The skin of primates. II. The skin of the slender loris (*Loris tardigradus*). Ibid., *18:* 19–44.

Montagna, W., K. Yasuda and R. A. Ellis 1960 The skin of primates. III. The skin of the slow loris (*Nycticebus coucang*). Ibid., *19:* 1–22.

Pearse, A. G. E. 1953 Histochemistry, Theoretical and Applied. Little, Brown & Co., Boston, Massachusetts.

Pocock, R. S. 1918 On the external characters of the lemurs and of *Tarsius*. Proc. Zool. Soc. Lond., *1:* 19–53.

Rutenburg, A. M., and A. M. Seligman 1935 The histochemical demonstration of acid phosphatase by a post-incubation coupling technique. J. Histochem. Cytochem., *3:* 455–470.

Schwalbe, G. 1910 Über die Richtung der Haare bei den Halbaffen. In: Vaeltzkows Reise in Ostafrika. Wiss. Ergebn., *4:* 1903–05.

Stowell, R. E., and C. S. Lee 1950 Histochemical studies of mouse liver after single feeding of carbon tetrachloride. Arch. Pathol., *50:* 519–537.

Sutton, J. B. 1887 On the arm-glands of the lemurs. Proc. Scientific meetings of the Zool. Soc., pp. 369-372.

Takeuchi, T., and H. Kuriaki 1955 Histochemical demonstration of phosphorylase in animal tissues. J. Histochem. Cytochem., *3:* 153–160.

Wilcox, H. H. 1950 Histology of the skin and hair of the adult chinchilla. Anat. Rec., *108:* 385–398.

PLATE 1

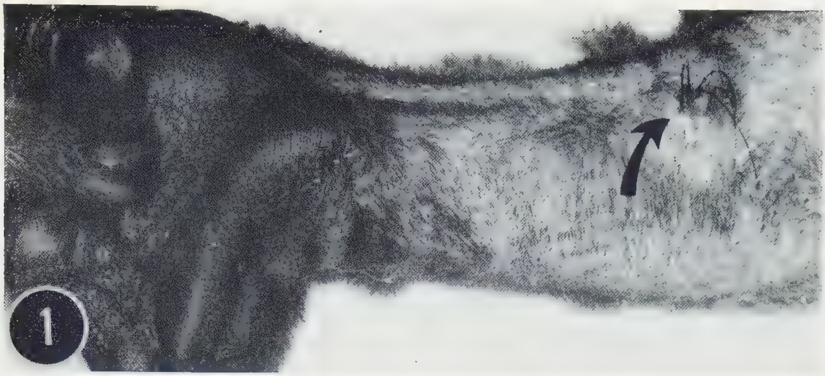
EXPLANATION OF FIGURES

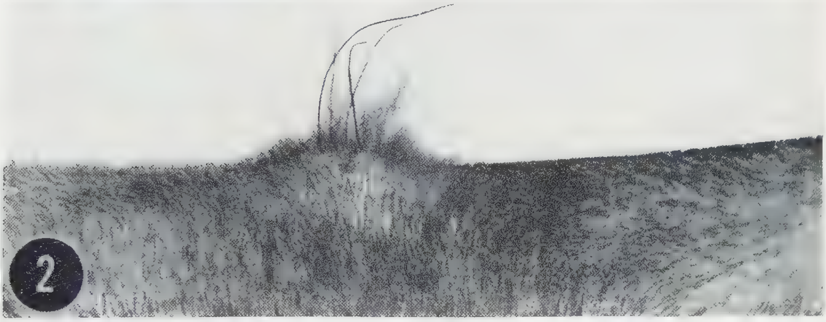
1 The flexor surface of the intact forearm. The arrow points to the tuft of vibrissae growing there.

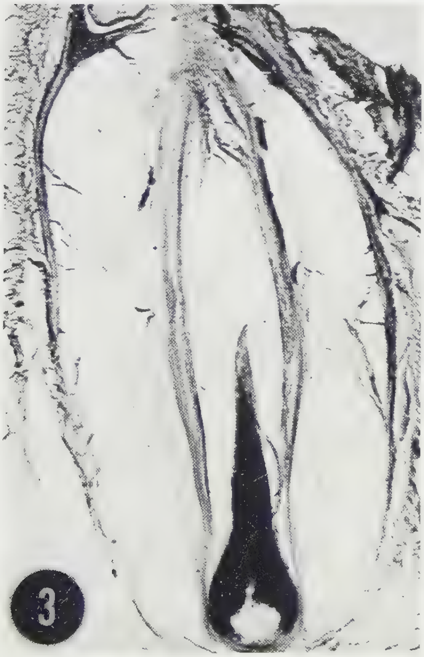
2 Profile of the tuft of vibrissae. The bristles grow from an elevation on the skin.

3 Frozen sections of the nevus on the medial surface of the forearm, showing one of the sinus hair follicles. × 60.

4 Fresh frozen section cut parallel to the surface, treated for succinic dehydrogenase, showing the "islands" of hair follicles. × 45.


1


2


3

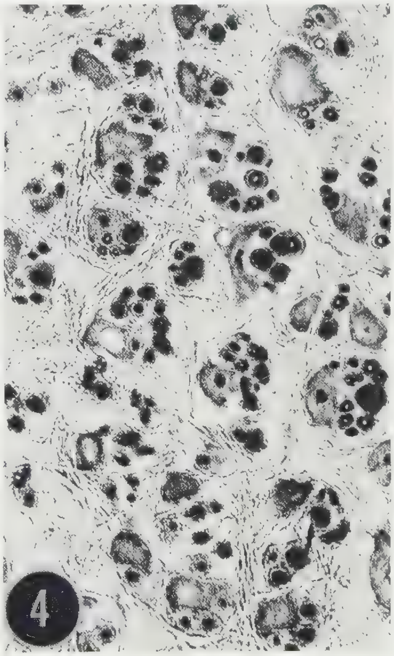

4

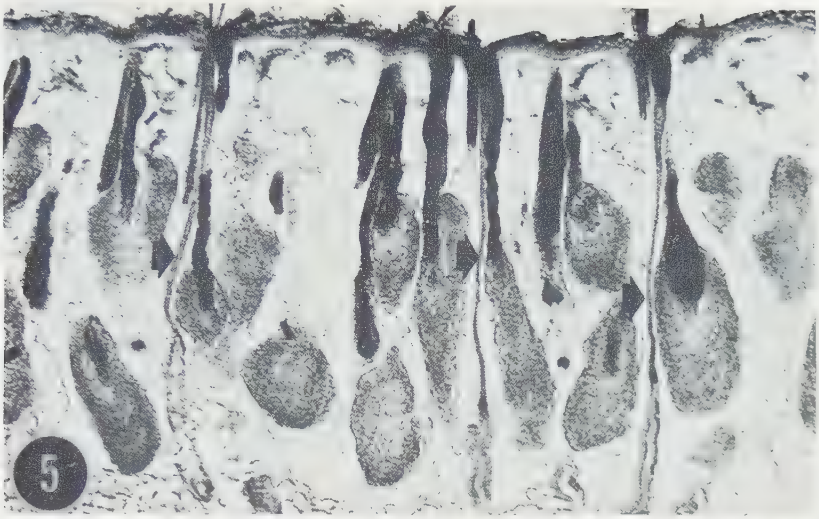
PLATE 2

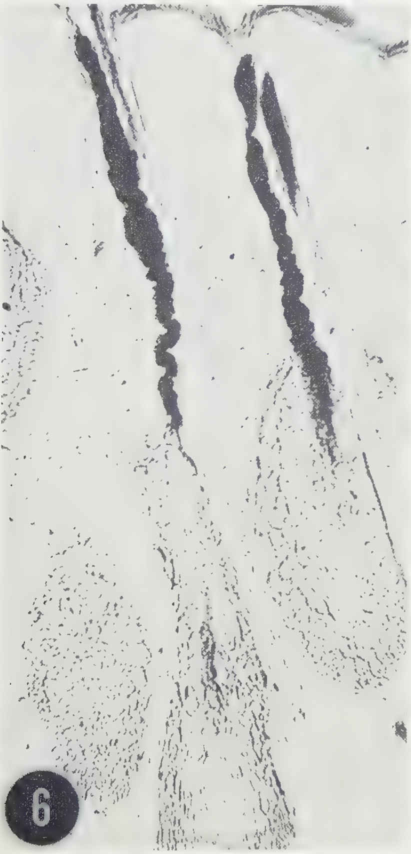
EXPLANATION OF FIGURES

5 Frozen section from the scalp, treated for alkaline phosphatase. The large, uniacinar sebaceous glands open directly to the surface by long, narrow ducts that contain black sebum. The three black arrows point to the slender ducts of the apocrine sweat glands.

6 Two sebaceous glands from the skin of the back colored lightly with Sudan VIII B. The long, tortuous duct contains darkly colored sebum and opens directly to the surface.

7 One multiacinar sebaceous gland from the scrotum, showing intense alkaline phosphatase activity. Contrast with figure 5, in which the uniacinar sebaceous glands are only slightly reactive.


5


6

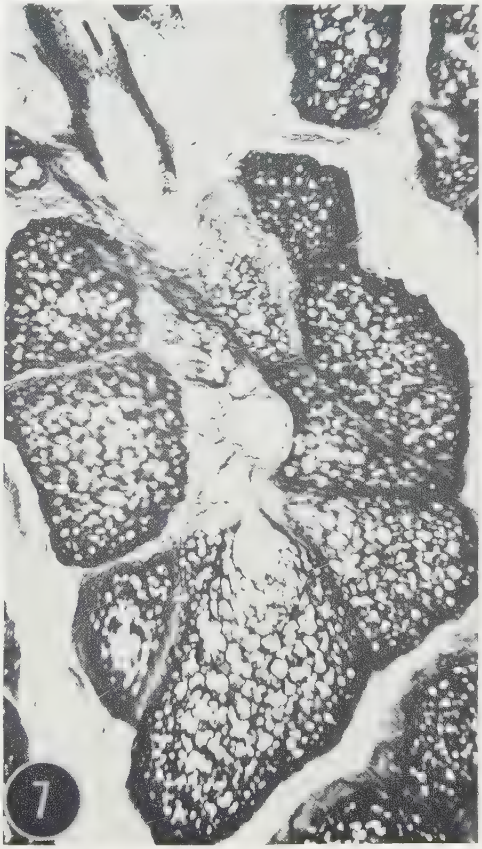

7

PLATE 3

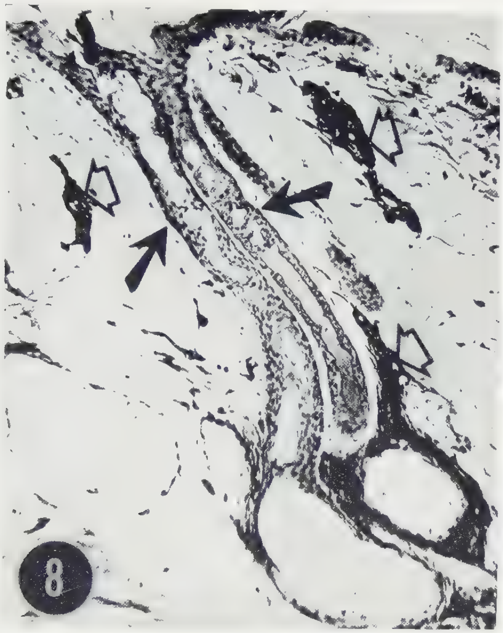
EXPLANATION OF FIGURES

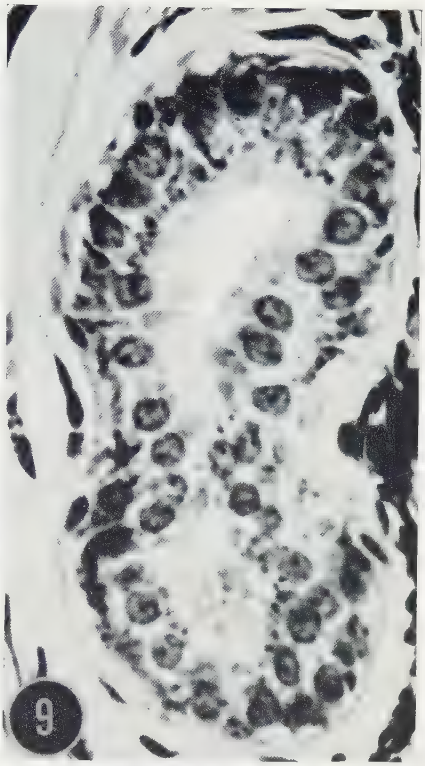
8 Section from the scalp treated with the PAS technique. The black arrows indicate the tortuous ducts of sebaceous glands; the white arrows indicate the perivascular accumulation of dermal melanocytes. × 100.

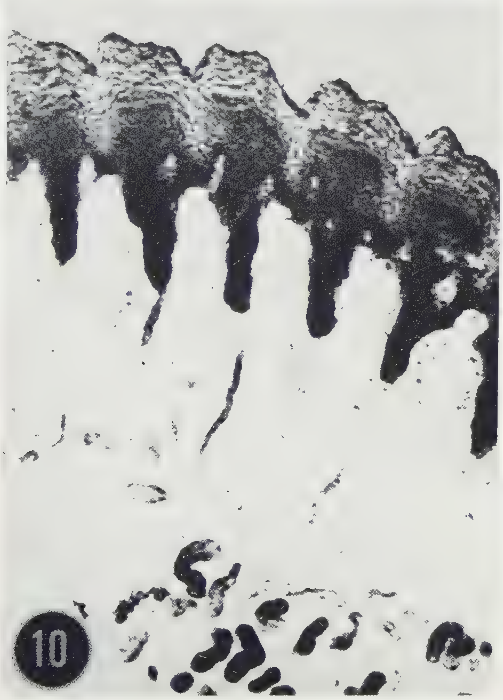
9 Section through a secretory segment of an apocrine gland from the cheek, treated with PAS. The black elements around the glands are melanocytes. × 250.

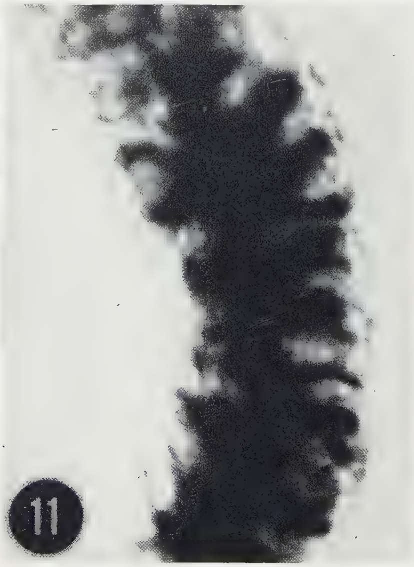
10 Skin of the palm showing amylophosphorylase in the sweat glands. The dark color in the epidermis is due largely to melanin. × 100.

11 Part of a secretory segment of a gland from the volar surface of the hand, showing alkaline phosphatase localized in the intercellular canaliculi. × 560.


8


9


10


11

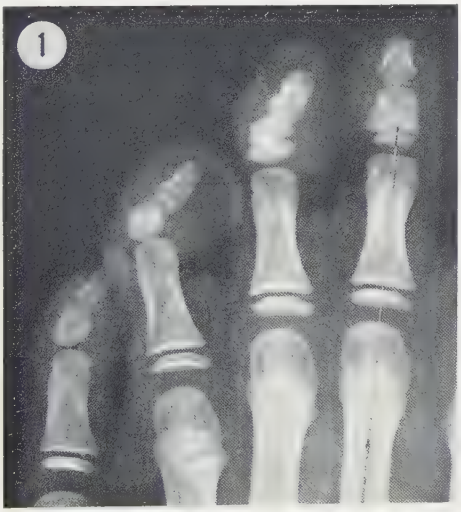
Radiological Studies of Variation in Ossification of the Foot.

III. CONE SHAPED EPIPHYSES OF THE PROXIMAL PHALANGES

P. VENNING
*Department of Anatomy, University College London,
London, England*

Radiographs of the feet of children reveal that epiphyses of the proximal phalanges vary considerably in shape. At one extreme (fig. 1) the epiphyseal plate and the adjacent surfaces of the ossified epiphysis and diaphysis form a nearly flat section across the phalanx. At the other extreme (fig. 2) the epiphysis is cone shaped with its apex projecting, axial to the shaft, into an accommodating crater of the diaphysis. This shape variation is probably continuously distributed since many forms intermediate to the extremes illustrated were seen. Proximal phalanges with extremely cone shaped epiphyses were sometimes noticeably short, and apparently poorly calcified. The diaphysis of such a phalanx was commonly marked by thin radio-opaque striae resembling the lines of arrested growth described by Harris ('33). In any one foot the degree of distal projection of these epiphyses was usually greatest in the middle toe and less on each succeeding toe on either side. It is doubtful whether this shape variation affects the proximal phalanx of the first toe; very occasionally the epiphysis on this toe resembled to some extent the cone shaped epiphyses of the other toes but the differences in appearance were too great to allow a comparable classification.

Similar cone shaped epiphyses, as well as axial craters of the diaphysis in the absence of epiphyseal ossification, have also been seen at the bases of the middle phalanges and metatarsals of the second–fifth toes on serial radiographs of the feet of infants. These structures were usually



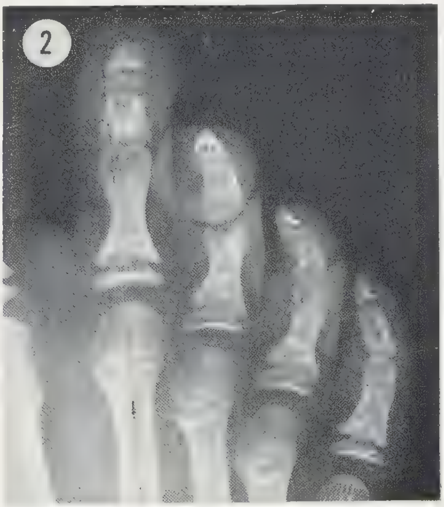


Fig. 1 The left foot of a girl aged 8, showing almost flat epiphyses of the proximal phalanges.

Fig. 2 The right foot of a girl aged 8, showing extremely cone shaped epiphyses of the proximal phalanges.

obliterated within a few months of their detection by the spread of diaphyseal ossification, and were sometimes succeeded by pseudo-epiphyses.

Brailsford ('43, '44) described extremely cone shaped epiphyses in the hands and feet of children with a congenital dysostosis. No reference has been discovered, however, to the occurrence of cone shaped epiphyses as a common morphological variation among apparently healthy children. Statistical data are presented here on the frequency distributions of these epiphyses of the proximal phalanges and their relations to morphological variations of the middle phalanges previously described (Venning, '54, '56a, '56b).

MATERIAL AND METHOD

The material used for statistical analysis was a collection of standard dorsi-plantar radiographs of the feet of more than 1800 school children. These children were all those attending in May, 1950 a group of schools serving a single residential area of Greater London. Their ages ranged from 4 to 15 years inclusive.

In addition a smaller collection of radiographs, including oblique and lateral views, of the feet of other children and some serial radiographs of infants' feet, was used to establish the anatomical relations of epiphyses and diaphyses described above.

The continuous shape variation of the epiphyses of the proximal phalanges was arbitrarily divided into conic and non-conic categories, and each ossified and unfused epiphysis was classified accordingly. If the distal surface of an ossified epiphysis formed a more or less pointed axial process that projected beyond the proximal rim of the diaphysis it was classed as conic. The films were assessed on three occasions separated by intervals of several weeks. Those epiphyses classified as conic on every occasion constituted the final sample of this category. No practicable system of measurements could be devised to give better discrimination than visual assessment.

RESULTS

1. Frequencies of cone shaped epiphyses with respect to age and sex

Table 1 shows the frequencies with which conic epiphyses were present in one or more proximal phalanges of the left feet in yearly age samples of boys and girls. Over the range of ages when none of the epiphyses have fused the frequencies show no consistent variation with respect to age. At older ages, when some epiphyses are fused, the frequencies of conic epiphyses among the remaining feet with no fusion are smaller. In the female samples this difference is highly significant ($\chi^2 = 15.76$, 1 degree of freedom; $P < 0.001$). Since there is no evidence that epiphyses tend to become less conic with increasing age, this result is interpreted to mean that conic epiphyses tend to fuse earlier. Inspection of the radiographs supports this conclusion, since signs of commencing fusion are frequently seen in the region of the apex of a cone shaped epiphysis at relatively early ages.

Cone shaped epiphyses are much more common among girls than boys, the difference being highly significant. No other differences between the sexes in the distribution of conic epiphyses were discovered.

Further results given below are based on the combined unfused age samples (4–10 years) of females only, since the number of conic epiphyses among males is too small for statistical analysis.

2. The distribution of conic epiphyses among the toes

Table 2 shows the distribution of cone shaped epiphyses among the toes of both feet. The frequencies show a highly significant tendency to bilateral symmetry, and no differences between the sides with respect to unilateral occurrences.

When only one toe in a foot had a conic epiphysis that toe was always the third; when more than one toe were affected these were always the third and one or more successive adjacent toes on one or both sides of the middle toe. Of the two toes immediately adjacent to the middle toe, the 4th was more frequently affected

TABLE 1

Frequencies, at different ages, of conic epiphyses of the proximal phalanges in children

Age at last birthday	Total in samples	% children with fusion of one or more epiphyses	A Children with no fusion	B Children with conic epiphyses	Col. B as % of Col. A
		Males			
4	24	Nil	24	Nil	Nil
5	88	Nil	88	7	7.9
6	82	Nil	82	3	3.7
7	88	Nil	88	8	9.1
8	61	Nil	61	5	8.2
9	72	Nil	72	8	11.1
10	98	Nil	98	8	8.2
11	91	Nil	91	10	11.0
12	93	Nil	93	6	6.5
Totals (4–12 yrs.)			697	55	7.9
13	109	5.5	103	6	5.8
14	92	20.7	73	2	2.7
15	14	35.7	9	Nil	Nil
Totals (13–15 yrs.)			185	8	4.3
		Females			
4	24	Nil	24	4	16.7
5	80	Nil	80	19	24.8
6	93	Nil	93	31	33.3
7	89	Nil	89	19	21.3
8	73	Nil	73	22	30.1
9	60	Nil	60	17	28.3
10	87	Nil	87	18	20.7
Totals (4–10 yrs.)			506	130	25.7
11	85	4.7	81	11	13.6
12	122	27.0	89	16	18.0
13	113	49.6	57	5	8.9
14	83	80.7	16	Nil	Nil
15	12	75.0	3	Nil	Nil
Totals (11–15 yrs.)			246	32	13.0

TABLE 2

Distribution of conic epiphyses of proximal phalanges among the toes of right and left feet of girls of 4–10 years inclusive

Toes with conic epiphyses of the proximal phalanges				Right feet							Left feet	
				None	— 3rd — —	2nd 3rd — —	— 3rd 4th —	2nd 3rd 4th —	— 3rd 4th 5th	2nd 3rd 4th 5th	Totals	%
		None		376	3	—	2	—	—	—	381	75.3
—	3rd	—	—	7	32	1	6	1	—	—	47	9.3
2nd	3rd	—	—	—	4	5	—	1	—	—	10	2.0
—	3rd	4th	—	2	6	—	20	5	—	—	33	6.5
2nd	3rd	4th	—	—	1	1	4	25	—	2	33	6.5
—	3rd	4th	5th	—	—	—	—	—	—	1	1	0.2
2nd	3rd	4th	5th	—	—	—	—	—	—	1	1	0.2
Right feet			Totals	385	46	7	32	32	—	4	506	
			%	76.1	9.1	1.4	6.3	6.3	Nil	0.8		

TABLE 3

Frequencies of the different combinations of morphological variants of the middle and proximal phalanges of left feet of girls

	Mid. phals.[1]				Proximal phalanges				
	Toes								
	2nd	3rd	4th	5th	N.C.	C	N.C.	C	Total
a	+	+	+	+	1	—	48	6	54
	+	+	+	—	47	6			
b	+	+	—	—			89	14	103
c	+	—	—	—			66	19	85
d	—	—	—	—			18	19	37
e	+	+	+	×			6	1	7
f	+	+	—	×			43	5	48
g	+	—	—	×	58	19	60	20	80
	+	—	×	×	2	1			
h	—	—	—	×	44	35	50	40	90
	—	—	×	×	1	5			
	—	×	×	×	5	—			
	+	—	+	—	1	—	Omitted		
	—	+	—	×	—	1			
Total							380	124	504

[1] +, middle phalanx with epiphysis; —, middle phalanx without epiphysis; ×, toe without middle phalanx; NC, epiphyses of proximal phalanges not conic; C, one or more epiphyses of prox. phals. conic.

than the second. The different combinations of toes with conic epiphyses may be interpreted in terms of a quantitative medio-lateral distribution of some factor promoting this form of epiphysis. Such a distribution would be greatest at the middle toe and diminish on either side as the distance from this toe increases, the lateral gradient tending to be less steep than the medial.

The diminishing order of frequency of conic epiphyses among the toes, third > fourth > second > fifth, corresponds to the usual sequence of onset of epiphyseal ossification among the proximal phalanges of these toes (Pyle and Sontag, '43; Harding, '52).

3. *Intra-foot correlations between conic epiphyses of the proximal phalanges and variations of the middle phalanges*

Table 3 shows the frequencies of morphological variations of the middle phalanges among feet with and feet without conic epiphyses of the proximal phalanges. These variations consist of middle phalanges with and without epiphyses (pseudoepiphyses are included in the latter category), and toes with and without middle phalanges. To facilitate statistical analysis the data have been simplified by the omission of the two cases of exceptional variations of the middle phalanges, and by combining the frequencies of others, as shown in the right-hand columns of the table. For example, variation in the number of phalanges is analyzed only for the 5th toe; the rare examples of other toes lacking the middle phalanx have been treated as if this phalanx was present without an epiphysis.

The amalgamation of frequencies in this way is justified on the assumption that the different variations of the middle phalanges form a related series (Venning, '56a). When, therefore, a variation is too rare to be used statistically it was supposed that more information would be obtained by combining it with the next variation of the series, than by excluding it from the data. The results given below will show that this assumption is only partially true. However, examination of the data shows that it makes no practical difference whether these rare variations are combined or excluded. Consequently it has not been considered necessary to change the procedure.

The hypothesis that any two of the three variable characters are not associated within feet may be tested by comparing samples that are matched with respect to the third. The following results are obtained.

a. There is a highly significant intra-foot association between the number of middle phalanges without epiphyses and conic epiphyses of the proximal phalanges. ($\chi^2 = 45.3$, 6 degrees of freedom.)

b. The highly significant intra-foot association previously reported (Venning, '56a) between the number of middle phalanges lacking epiphyses and the 5th toes lacking a middle phalanx is confirmed in the enlarged samples of the present material. ($\chi^2 = 61.6$, 6 degrees of freedom.)

c. There is no intra-foot association between conic epiphyses of the proximal phalanges and the presence or absence of the middle phalanx from the 5th toe. ($\chi^2 = 1.52$, 4 degrees of freedom.)

These results are interpreted as showing that the morphogenetic factor producing conic epiphyses of the proximal phalanges is independent of the factor causing the absence of the middle phalanx from the fifth toe, but that either of these factors may produce middle phalanges lacking epiphyses.

DISCUSSION

In considering the possible nature of the morphogenetic factors underlying conic epiphyses the observation that these epiphyses fuse relatively early may be significant. The different epiphyseal forms that occur in the digits of the foot may be arranged in series corresponding to differences in age at which osteogenic invasion from the diaphysis of the epiphyseal or presumptive epiphyseal cartilage occurs.

First in this series are those cases in which no epiphyseal structure is detectable radiographically at any age. In these cases the presumptive epiphyseal cartilage is presumably ossified from the diaphysis at an age when a specialized epiphyseal growth zone has either not been differentiated or constitutes only a transient barrier to the invasion. Parsons ('05) and Fell ('25) describe this kind of ossification in the embryonic long bones of birds.

Second are the pseudo-epiphyses. In these, early osteogenic invasion of the epiphyseal cartilage is localized within a more or less axial corridor. Around this corridor a peripheral ring of epiphyseal plate cartilage survives during a relatively prolonged period of growth (Posener, Walker and Weddell, '39).

Conic epiphyses of the proximal phalanges may be placed next in the series. In these the growth zone remains intact for a much longer period, but they resemble pseudo-epiphyses in that the axial part of this zone succumbs to osteogenic invasion before the peripheral part.

Finally, in non-conic epiphyses the growth cartilage remains intact for still longer periods and there is little or no difference in survival time between the center and periphery of this cartilage.

It appears therefore that the series of epiphyseal forms is related to a progressive decrease in the life of the epiphyseal plate that affects differentially the axial and peripheral parts of the cartilage. This differential within the growth zone suggests that the shape of conic epiphyses may be related to the presence of a radial gradient of some factor within the cartilage at some stage of differentiation.

SUMMARY

Epiphyses of the proximal phalanges of the feet exhibit a continuous variation in shape. At one extreme of this variation they are cone shaped with a central apex projecting distally into the diaphysis.

These conic epiphyses occur preferentially on the third toe and then on each successive toe on one or both sides of this toe, except the first. Conic epiphyses fuse relatively early and occur more commonly in girls than boys. They are significantly associated with middle phalanges lacking epiphyses, or with pseudo-epiphyses, in the same foot, but not associated with the absence of a middle phalanx from the 5th toe.

ACKNOWLEDGMENT

I wish to thank Professor J. Z. Young, F.R.S., for his advice and encouragement.

LITERATURE CITED

Brailsford, J. F. 1943 Variation in the ossification of the bones of the hand. J. Anat., Lond., 77: 170–175.

——— 1944 The Radiology of Bones and Joints, third ed. J. and A. Churchill, London.

Fell, H. B. 1925 The histogenesis of cartilage and bone in the long bones of the embryonic fowl. J. Morph., *49:* 417–460.

Harding, V. S. V. 1952 A method of evaluating osseous development from birth to 14 years. Child Devel., *23:* 247–271.

Harris, H. A. 1933 Bone Growth in Health and Disease. Oxford University Press.

Parsons, F. G. 1905 On pressure epiphyses. J. Anat. Phys., *39:* 402–412.

Posener, K., E. Walker and G. Weddell 1939 Radiographic studies of the metacarpal and metatarsal bones in children. J. Anat., Lond., *74:* 76–79.

Pyle, L., and L. W. Sontag 1943 Variability in onset of ossification in epiphyses and short bones of extremities. Am. J. Roentgenol., *49* 795–798.

Venning, P. 1954 Sib. correlations with respec to the number of phalanges on the fifth toe Ann. Eugen., Lond., *18:* 232–254.

——— 1956a Radiological studies of variations in the segmentation and ossification o the digits of the human foot. I. Variation in the number of phalanges and centers of ossification of the toes. Am. J. Phys. Anthrop., n.s *14:* 1–34.

——— 1956b Radiological studies of variations in the segmentation and ossification of the digits of the human foot. II. Variation in length of the digit segments correlated with differences of segmentation and ossification of the toes. Ibid., *14:* 129–152.

Radiological Studies of Variation in Ossification of the Foot

IV. THE LENGTH AND GROWTH OF BONES OF THE FOOT IN RELATION TO MORPHOLOGY

P. VENNING
Department of Anatomy, University College London, London, England

It has been reported that the length of a middle phalanx tends to be less (a) when it lacks an epiphysis, (b) when any other middle phalanx in the foot lacks an epiphysis, and (c) when the 5th toe lacks a middle phalanx (Venning, '56b). A highly significant intra-foot correlation between these conditions (Venning, '56a) suggests that both absence of epiphyses and absence of phalanx are manifestations of a generalized reduction of middle phalanges in the foot that is more pronounced in the post-axial digits.

These results were, however, obtained without taking into account a morphological variation of the proximal phalanges which is significantly correlated with the absence of epiphyses from middle phalanges but not with the absence of the phalanx itself from the 5th toe, and which also appears to be associated with short digit segments (Venning, '61).

The investigation now reported was undertaken to obtain more complete information about the relation of bone length and growth in the foot with each of the morphological variants of the digits.

The three variants separately considered in relation to bone length and growth are (1) the presence or absence of a middle phalanx in the 5th toe, (2) the presence or absence of epiphyses among the middle phalanges of the second, third and 4th toes (pseudo-epiphyses are classified as "absent"), and (3) the presence or absence of a "conic" epiphysis in one or more of the proximal phalanges. (This morphological variant of the proximal phalanges probably represents one tail of a continuous shape distribution of the epiphyses that has been classified into "not conic" and "conic" categories.)

Information about the criteria for identification and of these morphological variants on radiographs of children, their frequencies with respect to sex and digit, and their intra-foot correlations may be obtained from the communications already referred to.

MATERIAL AND METHOD

The material consists of dorsi-plantar radiographs of the feet of about 500 schoolgirls aged 4 to 10 years inclusive. Within this age range nearly all relevant epiphyses are ossified but not yet fused and it was possible to identify with reasonable confidence each skeletal variant. The children represented were all those attending a group of schools in Greater London during May, 1950, and probably include nearly every girl of this age living in the urban locality. The age of each child was known to the nearest month.

Each radiograph was taken with the child seated, the knees partly flexed, and the feet resting side by side with their plantar surfaces on the film. The x-ray tube was centered 100.0 cm perpendicularly over a point on the film midway between the feet at the level of the heads of the second metatarsals. Positioning was standardized by using a fixed frame to hold the film in a constant relationship to the tube; the feet were then placed with reference to markings on this frame.

The radiographs were examined at about × 3 magnification and the following dimensions of *left* feet were measured to the nearest 0.25 mm:

1. the lengths of all segments of the first digit, and of the middle phalanges and metatarsals of the other digits, measured along the presumed long axis of each bone between perpendiculars to this axis tangential to either end of the bone;
2. the length of each proximal phalanx of the second–fifth toes coincident with the presumed long axis of the bone;
3. the length of medial cuneiform, and of the cuboid, measured in each case along the long axis (produced) of the 4th metatarsal, between the pair of perpendiculars to this axis tangential to the bone in question;
4. the anterior protrusion of the first metatarsal beyond the second (negative and positive values), and of the second metatarsal beyond the 5th, measured in each case along the long axis of second metatarsal between perpendiculars to this axis tangential to the anterior ends of the first and second, and second and 5th metatarsals respectively.

Table 1 gives the principal parameters of each dimension for the whole material. The coefficients of linear regression of length on age show that all the dimensions, except the anterior protrusion of the first metatarsal beyond the second, are significantly dependent upon age.

The material was divided into 16 samples corresponding to different combinations of morphological characters in the digits of left feet (table 2). The mean length of each dimension, estimated at a standard age $X_0 = 92.5$ months, is given for each sample (table 3). The standard error of each mean,

$$\sqrt{S^2\left(\frac{1}{n}+\frac{(X_0-\bar{X})^2}{Cxx}\right)}$$

may be obtained from the tabulated values of the factors S^2 (the residual variance of length about the regression estimated for each dimension by averaging over-all samples), and

$$\gamma = \frac{1}{n}+\frac{(X_0-\bar{X})^2}{Cxx}.$$

The coefficient of linear regression of length on age of each dimension is given for each sample (table 4). The values of the factor $1/Cxx$, ($\times 10^7$ for convenience), are tabulated so that the standard error of each regression, $\sqrt{S^2/Cxx}$, may be obtained.

The values of the regressions (mm per month) are taken as estimates of the

TABLE 1

Mean length (estimated at a standard age of 92.5 months), estimated variance, and coefficient of linear regression of length on age (mm per month) for each dimension of the whole material irrespective of morphological differences

Dimensions	N	Mean length	σ^2	b
		mm		
Term. phal. 1st digit	499	19.64	2.468	0.0858
Mid. phal. 2nd digit	497	9.22	2.126	0.0504
Mid. phal. 3rd digit	492	7.83	2.373	0.0392
Mid. phal. 4th digit	485	6.37	1.324	0.0293
Mid. phal. 5th digit	276	5.00	0.455	0.0239
Prox. phal. 1st digit	499	24.12	4.866	0.1390
Prox. phal. 2nd digit	499	20.21	2.748	0.0907
Prox. phal. 3rd digit	499	18.27	2.794	0.0795
Prox. phal. 4th digit	499	17.05	2.116	0.0747
Prox. phal. 5th digit	498	15.57	1.703	0.0640
Metatarsal 1st digit	497	48.50	10.551	0.2510
Metatarsal 2nd digit	494	53.14	14.079	0.2585
Metatarsal 3rd digit	493	50.98	12.762	0.2385
Metatarsal 4th digit	496	49.58	12.284	0.2363
Metatarsal 5th digit	497	49.41	15.264	0.2745
Met. protrusion 1st > 2nd	498	0.88	4.800	0.0023
Met. protrusion 2nd > 5th	498	22.87	7.952	0.0854
Medial cuneiform	500	24.68	6.515	0.2090
Cuboid	500	25.35	3.816	0.1406

TABLE 2

The number of left feet in each morphological sample

The number measured in any sample was sometimes slightly less, for a given dimension, than the number shown above, due to that dimension being unmeasurable on one or more film.

Sample	Morphological classification[1]					Nos. left feet
	Middle phalanges				Prox. phals.	
	2nd	3rd	4th	5th		
1	+	+	+	—	NC	48
2	+	+	+	×	NC	6
3	+	+	—	—	NC	89
4	+	+	—	×	NC	43
5	+	—	—	—	NC	66
6	+	—	—	×	NC	60
7	—	—	—	—	NC	18
8	—	—	—	×	NC	50
9	+	+	+	—	C	6
10	+	+	+	×	C	1
11	+	+	—	—	C	14
12	+	+	—	×	C	5
13	+	—	—	—	C	19
14	+	—	—	×	C	20
15	—	—	—	—	C	19
16	—	—	—	×	C	40
Total						504

[1] +, Middle phalanx epiphysis present; —, middle phalanx epiphysis absent; ×, middle phalanx absent; NC, proximal phalanges epiphyses, not conic; C, proximal phalanges epiphyses, one or more conic. Sample 1, 6, 8, 14 and 16 is each comprised of an amalgamation of the morphological classification indicated with other rare classifications considered equivalent (see Venning, '61, table 3 for full breakdown).

mean growth rates of the dimensions. The linear relationship between length and age assumed in these estimates is probably a good enough approximation over the age range covered by the material. Scatter diagrams revealed no obvious departures from linearity. Some departure from linearity, overestimation of regression coefficients, and underestimation of mean lengths may be expected in the case of the medial cuneiform and of the 5th metatarsal due to incomplete ossification in some of these bones at some ages.

It will be noticed that the estimates of variance, S^2 in table 3, differ from and are usually smaller than the estimates σ^2 shown in table 1. This is because the former but not the latter take account of differences in length between samples.

The following null hypotheses were tested—that the mean length, or growth rate, of any dimension is not greater in feet (a) with a middle phalanx present in the 5th toe, (b) with an epiphysis present in the middle phalanx of the second, third or 4th toe, (c) with non-conic epiphyses present in all the proximal phalanges, (d) with all three characters present, than in feet with the respective character(s) not present in each case.

The mean lengths, or growth rates, of each dimension were compared in matched pairs of samples that differed from each other only in respect of the character or characters under consideration. Only one pair of matched samples is available for testing hypothesis (d) (samples 1 and 16: see table 2). For each of the other hypotheses a set of matched pairs is available, and tests of significance were carried out on the difference in mean length, or in regression, in each matched pair, and on the sum of differences over each set of pairs. The latter tests are much the more informative and only these results have been tabulated. Positive differences, i.e., in a direction contrary to that expected by the hypotheses, were tested for significance, and the probabilities that these differences would have occurred by chance, supposing the hypotheses to be true, are given for one tail of the distribution of Student's t. Negative differences are, of course, excluded from consideration by the hypothesis. They were in all cases very small. Sample 10,

TABLE 3

Mean length (mm) estimated at a standard age (92.5 months) of each dimension for each sample

The standard error of the difference, or sum of differences, between means of a dimension is $S\sqrt{\Sigma\gamma}$. The value of γ for given sample is constant for all dimensions except when the number of feet measured varies. In these cases the value of γ for the particular dimension is indicated by the suffix a, b or c.

Dimensions	S^2	Samples														
		1	2	3	4	5	6	7	8	9	11	12	13	14	15	16
Term. ph. 1st dig.	2.798	20.10	19.28	19.58	19.93	20.11	19.83	19.53	19.66	18.90	18.22	19.16	19.44	19.68	18.97	19.21
Mid. ph. 2nd dig.	1.096	10.66	10.07	10.00	09.92	09.56	09.25	08.45	07.52	09.71	09.37a	09.26a	08.94	08.95	07.97	07.50
Mid. ph. 3rd dig.	0.926	09.96	09.26	08.99	08.70	07.20	06.86	07.55	06.32a	08.70	08.47	08.47a	07.38	06.96	07.08a	06.28
Mid. ph. 4th dig.	0.608	08.32	06.73	06.78	06.26	06.27	05.66a	06.55	05.42b	07.61	06.73	06.78a	06.49	05.80a	06.08	05.20a
Mid. ph. 5th dig.	0.414	05.32a		05.02		04.80		04.98		05.62	05.08		04.80		04.81	
Prox. ph. 1st dig.	4.436	25.31	23.74	24.51	24.55	24.56	23.66	24.14	24.16	23.84	23.76	23.85	23.46	23.62	22.78	22.83
Prox. ph. 2nd dig.	2.284	21.06	21.37	20.55	20.72	20.75	20.16	20.75	20.27	19.23	19.21	19.79	18.84	19.92	18.74	18.81
Prox. ph. 3rd dig.	1.997	19.16	20.16	18.68	18.88	18.99	18.47	18.89	18.46	17.20	17.06	17.95	16.90	17.33	16.17	16.41
Prox. ph. 4th dig.	1.706	17.84	18.14	17.35	17.51	17.60	17.14	17.35	17.07	16.35	16.20	16.47	16.11	16.34	15.51	15.73
Prox. ph. 5th dig.	1.561	16.03	15.64	15.67	16.11a	15.72	15.66	16.06	15.67	15.12	14.67	15.17	14.96	15.35	14.72	14.84
Metat. 1st dig.	10.053	49.73	48.97	48.59	49.08	49.14a	48.25	49.26	48.53	46.92	47.99a	48.71	47.32	48.57	46.98	46.91
Metat. 2nd dig.	13.750	54.71b	52.67	53.46	52.97	53.30a	53.06	54.45	52.72	52.35	53.25a	53.32	52.10	53.68	52.29a	51.48
Metat. 3rd dig.	12.422	52.41c	50.81	51.46	50.59	51.44a	50.89	52.24	50.54	50.17	50.57a	50.55	49.97	50.80	50.35a	49.44
Metat. 4th dig.	11.976	51.00a	50.06	49.97	49.36	50.13a	49.60	50.64	49.10	48.59	48.81a	49.10	48.60	49.45	48.33	48.44
Metat. 5th dig.	14.612	50.85	49.97	49.75	49.17	50.26a	49.12	51.12	49.17	48.96	48.54a	49.50	47.96	48.98	48.28	47.80
Met. protr. 1st > 2nd	4.715	00.87	01.67	00.93	01.71	01.45a	00.52	00.61	00.92c	01.22	00.13a	−00.24	00.21	00.58	00.23	00.71
Met. protr. 2nd > 5th	7.911	23.08	24.25	22.55	23.91	22.49a	22.82	23.45	22.37c	22.50	23.49a	21.74	24.09	23.28	22.67	22.68
Med. cuneiform	6.390	25.39	25.11	24.47	25.27	24.82	24.36	26.02	24.10c	24.40	24.81	24.78	24.50	24.55	24.97	24.29
Cuboid	3.863	25.67	25.69	25.35	25.49	25.40	25.43	25.87	25.28c	25.15	26.34	25.84	25.21	25.41	25.32	24.36
	γ	0.02198	0.6782	0.01119	0.02532	0.01565	0.01703	0.05638	0.02073	0.1669	0.09875	0.2282	0.05269	0.05108	0.05480	0.02569
	γa	0.02219			0.02645	0.01589	0.01762		0.02290		0.1008	0.2683		0.05433	0.05639	0.02875
	γb	0.02240							0.02318							
	γc	0.02265							0.02046							

TABLE 4

Coefficients of regression of length on age (mm per month) of each dimension for each sample

The coefficients are positive except where indicated. The standard error of the difference, or sum of differences, between regressions of a dimension is $S\sqrt{\Sigma\ 1/Cxx}$. Values of S^2 are given in table 3. Variation of 1/Cxx within a sample is indicated by the suffixes a, b, c.

Dimensions	Samples														
	1	2	3	4	5	6	7	8	9	11	12	13	14	15	16
Term. ph. 1st dig.	0.076	0.108	0.085	0.089	0.101	0.081	0.109	0.088	0.098	0.049	0.093	0.071	0.082	0.050	0.081
Mid. ph. 2nd dig.	0.061	0.066	0.048	0.067	0.070	0.048	0.047	0.035	0.063	0.040a	0.044a	0.047	0.034	0.027	0.034
Mid. ph. 3rd dig.	0.052	0.049	0.041	0.046	0.043	0.025	0.042	0.027a	0.045	0.045	0.028a	0.039	0.003	0.037a	0.032
Mid. ph. 4th dig.	0.036	0.011	0.024	0.017	0.038	0.030a	0.036	0.026b	0.041	0.030	0.029a	0.033	0.003a	0.030	0.032a
Mid. ph. 5th dig.	0.019a		0.018		0.032		0.025		0.056	0.029		0.019		0.026	
Prox. ph. 1st dig.	0.148	0.141	0.135	0.149	0.159	0.109	0.169	0.152	0.205	0.132	0.160	0.125	0.113	0.097	0.117
Prox. ph. 2nd dig.	0.089	0.129	0.084	0.106	0.105	0.076	0.112	0.088	0.092	0.059	0.088	0.082	0.113	0.067	0.088
Prox. ph. 3rd dig.	0.075	0.133	0.074	0.091	0.196	0.063	0.100	0.080	0.105	0.056	0.065	0.078	0.071	0.051	0.077
Prox. ph. 4th dig.	0.072	0.102	0.070	0.085	0.089	0.063	0.092	0.076	0.094	0.061	0.069	0.073	0.062	0.044	0.068
Prox. ph. 5th dig.	0.062	0.071	0.060	0.071a	0.075	0.055	0.097	0.066	0.110	0.051	0.048	0.053	0.043	0.039	0.052
Metat. 1st dig.	0.204	0.277	0.250	0.290	0.291	0.216	0.297	0.255	0.316	0.219a	0.158	0.247	0.198	0.203	0.215
Metat. 2nd dig.	0.234b	0.256	0.269	0.284	0.296	0.215	0.339	0.253	0.344	0.221a	0.221	0.264	0.183	0.261a	0.231
Metat. 3rd dig.	0.228c	0.247	0.251	0.267	0.265	0.195	0.322	0.228	0.313	0.198a	0.203	0.252	0.161	0.239a	0.219
Metat. 4th dig.	0.203a	0.275	0.248	0.266	0.268	0.200	0.324	0.222	0.328	0.208a	0.246	0.240	0.164	0.226	0.221
Metat. 5th dig.	0.240	0.362	0.275	0.322	0.313	0.234	0.392	0.279	0.318	0.247a	0.297	0.262	0.186	0.248	0.232
Met. protr. 1st > 2nd	0.009[1]	0.033	0.003	0.010	0.017	0.007	0.018[1]	0.007c	0.013	0.003[1]a	0.110[1]	0.036[1]	0.012	0.011[1]	0.003[1]
Met. protr. 2nd > 5th	0.094	0.097	0.097	0.085	0.116	0.067	0.093	0.065c	0.125	0.070a	0.030	0.081	0.031	0.061	0.092
Med. cuneiform	0.189	0.227	0.206	0.207	0.239	0.181	0.265	0.219c	0.159	0.215	0.198	0.220	0.175	0.212	0.199
Cuboid	0.138	0.173	0.144	0.132	0.153	0.128	0.154	0.146c	0.167	0.172	0.110	0.161	0.109	0.138	0.117
(× 10^7) 1/Cxx	489	11976	219	511	321	321	1217	346	5350	2938	5913	1092	1484	1269	541
(× 10^7) 1/Cxxa	509			538		326		377		3031	6053		1556	1463	597
(× 10^7) 1/Cxxb	542							387							
(× 10^7) 1/Cxxc	582							335							

[1] Negative values.

containing only one foot, could not of course be used for these comparisons.

The relative anterior protrusions of the metatarsals were exceptions to the above procedure. There was no presumption that these measurements would vary in any particular direction with respect to the characters. The hypothesis tested for these dimensions was that they would not *differ* as between the presence and absence of the characters, and the probabilities are therefore given in respect to both tails of the distribution of t.

In assessing the results the effects of lack of independence between variables must be considered. First, of course, the length and regression of a dimension are mutually dependent. Second, there is likely to be variation of more than one morphological character between matched samples, since the characters are probably continuous variables, or expressions of continuous variables, and in some cases are mutually correlated. Classification into discrete "present" and "not present" categories cannot eliminate within-category variation. Third, there will be intra-foot correlations between the parts measured in respect to both length and regression.

The consequence of lack of independence will be a tendency to obtain similar results as between length and regression, as between correlated characters, and as between different dimensions. Correspondences between results cannot therefore be regarded as providing independent confirmation of a particular relationship between length, or regression, and morphology. Conversely a divergence of results may be accepted, a fortiori, as evidence of a real difference in this respect.

RESULTS

The results of the tests of significance on the sums of differences of mean lengths and of mean growth rates are given in table 5.

1. Presence or absence of the middle phalanx of the 5th toe

None of the dimensions vary in length or growth rate with respect to this character, except the middle phalanges. These phalanges tend to be shorter when the 5th toe lacks a middle phalanx. The growth rate of only one of the middle phalanges was less when the 5th toe phalanx was absent, and this result was only marginally significant. It must therefore be considered doubtful whether any of the growth rates varied with respect to this character.

2. Presence or absence of epiphyses of middle phalanges

The tabulated results refer only to comparisons between feet with these epiphyses all present or all absent. They indicate that all middle phalanges, and proximal phalanges of the second, third and 4th toes are shorter when the epiphyses are absent. Again only a marginally significant difference in growth rate of one middle phalanx was found. Neither the length nor growth rate of any other dimension was significantly different.

The results of comparisons of single pairs of matched samples, (not tabulated) indicated that in general the greater the number of middle phalanges lacking epiphyses the shorter the length of any particular middle phalanx.

3. Presence or absence of conic epiphyses

The majority of dimensions are shorter in feet with conic epiphyses of one or more proximal phalanges. The only dimensions not affected are the middle phalanges of the 4th and 5th toes, the two tarsal bones, and the anterior protrusion of the second metatarsal beyond the 5th. Only two growth rates showed marginally significant differences.

4. Presence of 5th toe middle phalanx, epiphyses of middle phalanges and non-conic epiphyses, or absence of all these characters

The lengths of nearly every dimension, including the tarsal bones, are shorter when the characters specified are absent. The only exceptions are the anterior protrusions of the metatarsals. The growth rates of the middle phalanges of the second and third toes are also less when the characters are absent.

TABLE 5

Results of comparisons of differences of mean lengths and growth rates of each dimension in respect of the presence or absence of morphological characters

Plus signs (+) indicate differences contrary to the null hypotheses tested. Probabilities, for one tail of the distribution of t, are given with respect to the following values: 0.0500; 0.0250; 0.0100; 0.0050; 0.0025; 0.0010; 0.0005. Values > 0.0500 are considered not significant (NS). Degrees of freedom of each dimension are $\Sigma(n-2)$ over all samples.

Dimensions	D.F.	Probabilities that mean length, and growth, are not greater when							
		1 Middle phalanx is present in 5th toe		2 Epiphyses are present in middle phalanges		3 Conic epiphyses absent from proximal phals.		4 Characters 1, 2, and 3 occur together	
		Length	Growth	Length	Growth	Length	Growth	Length	Growth
Term. ph. 1st digit	468	− NS	− NS	+ NS	+ NS	$+ < 0.0005$	+ NS	$+ < 0.0100$	− NS
Mid. ph. 2nd digit	466	$+ < 0.0250$	+ NS	$+ < 0.0005$	$+ < 0.0500$	$+ < 0.0005$	$+ < 0.0500$	$+ < 0.0005$	$+ < 0.0100$
Mid. ph. 3rd digit	461	$+ < 0.0005$	$+ < 0.0500$	$+ < 0.0005$	+ NS	$+ < 0.0100$	+ NS	$+ < 0.0005$	$+ < 0.0250$
Mid. ph. 4th digit	454	$+ < 0.0005$	+ NS	$+ < 0.0005$	− NS	+ NS	− NS	$+ < 0.0005$	+ NS
Mid. ph. 5th digit	260			$+ < 0.0010$	+ NS	− NS	− NS	$+ < 0.0025^1$	− NS^1
Prox. ph. 1st digit	468	+ NS	+ NS	+ NS	+ NS	$+ < 0.0005$	+ NS	$+ < 0.0005$	+ NS
Prox. ph. 2nd digit	468	− NS	− NS	$+ < 0.0500$	+ NS	$+ < 0.0005$	+ NS	$+ < 0.0005$	+ NS
Prox. ph. 3rd digit	468	− NS	− NS	$+ < 0.0025$	+ NS	$+ < 0.0005$	+ NS	$+ < 0.0005$	− NS
Prox. ph. 4th digit	468	− NS	− NS	$+ < 0.0250$	+ NS	$+ < 0.0005$	+ NS	$+ < 0.0005$	+ NS
Prox ph. 5th digit	467	− NS	+ NS	+ NS	+ NS	$+ < 0.0005$	+ NS	$+ < 0.0005$	+ NS
Metat. 1st digit	466	− NS	+ NS	+ NS	+ NS	$+ < 0.0010$	$+ < 0.0500$	$+ < 0.0005$	+ NS
Metat. 2nd digit	463	+ NS	+ NS	+ NS	− NS	$+ < 0.0500$	+ NS	$+ < 0.0005$	+ NS
Metat. 3rd digit	462	+ NS	+ NS	+ NS	− NS	$+ < 0.0100$	+ NS	$+ < 0.0005$	+ NS
Metat. 4th digit	465	+ NS	+ NS	+ NS	+ NS	$+ < 0.0050$	+ NS	$+ < 0.0005$	− NS
Metat. 5th digit	466	+ NS	+ NS	+ NS	+ NS	$+ < 0.0050$	+ NS	$+ < 0.0005$	+ NS
Met. protr. 1st > 2nd	467	− NS^2	− NS^2	+ NS^2	− NS^2	$+ < 0.0500^2$	+ NS^2	+ NS^2	− NS^2
Met protr. 2nd > 5th	467	+ NS^2	+ NS^2	+ NS^2	+ NS^2	+ NS^2	+ NS^2	+ NS^2	+ NS^2
Medial cuneiform	469	+ NS	+ NS	+ NS	− NS	+ NS	+ NS	$+ < 0.0250$	− NS
Cuboid	469	+ NS	+ NS	+ NS	+ NS	+ NS	+ NS	$+ < 0.0025$	+ NS

---

[1] Characters 2 and 3 only.

[2] Probability for both tails of t.

DISCUSSION

The most striking features of the results are the variations they reveal in the extent to which bone length in the foot is dependent on the different morphological characters, and the contrast between the common occurrence of length dependence and the virtual absence of growth dependence on these characters.

Differences among the characters in respect of length dependence are greatest as between the middle phalanx of the 5th toe and the epiphyses of the proximal phalanges. The presence or absence of the former character is related to length differences of middle phalanges only. It was previously suggested that length variation of presumptive middle phalanx tissue was a morphogenetic determinant of this character (Venning, '56b). By contrast the presence or absence of conic epiphyses of the proximal phalanges appears to be related to the lengths of most of the digit segments. It must be supposed that variation of this character is the expression of differences in some characteristic of cartilage differentiation that affects the foot, or at least the digits, as a whole. The results obtained in respect of the dependence of length on the presence or absence of the epiphyses of the middle phalanges are intermediate to those obtained for the other two characters.

These differences between the characters are consistent with an hypothesis, based on the intra-foot correlations between the characters, that the morphogenetic factor determining the presence or absence of the middle phalanx of the 5th toe is different from that determining the conic or non-conic epiphyses of the proximal phalanges, and that either or both these factors determine the presence or absence of epiphyses of the middle phalanges (Venning, '61).

Very few of the significant length differences are accompanied by corresponding significant differences in growth rates. This can be explained in two ways. First, it may be supposed that a length difference is initially established at the time of segmentation of the foot skeleton, and consequently does not depend upon subsequent growth differentials. This explanation would be consistent with the suggested morphogenetic determination of the presence or absence of a middle phalanx. Alternatively, a length difference may have been caused by differences in growth rate operating after segmentation but at ages earlier than those represented in the material. Although the linear regressions of length on age, used in this study as estimates of mean growth rate, appear to fit the data over the age range available, it is evident, from the values given in table 1, that at earlier ages the absolute growth rates of the different dimensions must often have been many times greater than those estimated. At faster growth rates, differences in rates of the same relative magnitude as those found not significant in the present material, might well produce the observed differences in length in quite a short time.

There is no evidence from the present study as to whether one or both of these explanations are applicable.

SUMMARY

Measurements of the length of digit segments, of the medial cuneiform and cuboid, and of relative metatarsal protrusion were made on standard dorsiplantar radiographs of the left feet of girls.

The dependence of the length, and of the regression of length on age, of each measurement on the following morphological variables was investigated: (a) the presence or absence of the middle phalanx of the 5th toe, (b) the presence or absence of epiphyses of the middle phalanges, and (c) the presence or absence of conic epiphyses of the proximal phalanges.

When the 5th toe lacks a middle phalanx all the middle phalanges tend to be shorter. When the middle phalanges lack epiphyses all the middle phalanges and some proximal phalanges tend to be shorter. When conic epiphyses are present in one or more proximal phalanges most of the dimensions measured were shorter.

Very few of the regressions were significantly dependent on any of the morphological variables.

The results are considered to be consistent with intra-foot correlations of the

morphological variables previously investigated.

ACKNOWLEDGMENT

I am indebted to Mrs. D. M. Harris of the Department of Statistics at University College London, for advice on statistical procedures, and to Professor J. Z. Young for encouragement and criticism.

LITERATURE CITED

Venning, P. 1956a Radiological studies of variations in the segmentation and ossification of the digits of the human foot. I. Variation in the number of phalanges and centers of ossification of the toes. Am. J. Phys. Anthrop., n.s. *14:* 1–34.

——— 1956b Radiological studies of variations in the segmentation and ossification of the digits of the human foot. II. Variation in length of the digit segments correlated with differences of segmentation and ossification of the toes. Ibid., *14:* 129–152.

——— 1961 Radiological studies of variation in ossification of the foot. III. Cone shaped epiphyses of the proximal phalanges. Ibid., *19:* 131–136.

Anthropometric Data Presented in Three-Dimensional Forms[1]

MILTON ALEXANDER, ROBERT S. ZEIGEN AND IRVIN EMANUEL
Anthropology Section, Aerospace Medical Division,
Wright Air Development Division, Wright-Patterson Air Force Base, Ohio

The physical anthropologist, in one of his capacities, describes man's variability anthropometrically. At the same time, these anthropometric data may be used to design equipment which must accommodate this acknowledged variability. This paper will consider a number of recent approaches by the Air Force to "statistically" demonstrate and accommodate variability without attempting to define its causes.

Of major importance to the physical anthropologist is the recognition that he must interpret his data before the designer or engineer can correctly apply these. This results from the lack of appreciation by designers and engineers of the statistical concepts generally used when presenting anthropometric data. It is true that when dealing with workspace envelopes employing gross measurements, designers have successfully applied anthropometric data as they are frequently reduced in terms of means, standard deviations and percentiles (Hertzberg, '60). Hertzberg, Daniels and Churchill ('54), in their report of an anthropometric survey of more than 4,000 Air Force flying personnel, serve as an excellent example of this method of data presentation. Table 1 illustrates the presentation of such information for one of 132 dimensions measured in this survey (values in all tables are in inches and pounds). However, experience shows that this analysis is ineffective when used for designing close-fitting personal flying equipment such as pressure suits, oxygen masks and helmets. Each contractor adapts the data to his own sizing standards without fully appreciating the statistics involved, resulting in their frequent misapplication. One of the major objectives of the present Air Force effort is to eliminate this situation by standardizing the sizing of all personal protective equipment. The importance of such a program to the physical well being of flying personnel cannot be over-emphasized. When an item of protective equipment does not fit properly or may cause discomfort it may be discarded entirely or, if worn, fail to provide the desired protection when called upon to function in an emergency.

Recognizing that there is this gap between the anthropological data and the ability of designers to effectively utilize these, United States military agencies have developed three-dimensional representations of the data. The three-size plastic manikin series constructed by Randall ('43) demonstrates one such effort for the body as a whole. However, these manikins, in general, reflected statistical data similar to those in table 1, and they found their greatest service in gross clearance problems rather than in designing the close-fitting protective equipment which is our immediate concern. Since it is extremely difficult to integrate the various segments of the body into an objective series of items for the sizing of protective equipment, more intensive research was directed at resolving sizing problems for the individual segments of the body, especially for the head. Three-dimensional representations of the head were described by Randall and Damon ('42), Koepnick and Benton ('44), the Chemical Warfare Service under Cosentino ('45), Cole et al. ('58) and Saul and Truett (unpublished manuscript). Statistical headforms built to anthropometric data analyzed in these reports were used in helmet, oxygen mask, respirator, and similar sizing problems.

---

[1] Based on a paper delivered at the 29th Annual Meeting of the AAPA, 1960.

TABLE 1[1]

Conventional presentation of anthropometric data. Dimension-head circumference[2]

Percentile values		
%	*cm*	*in.*
1	53.4	21.0
2	53.9	21.2
3	54.2	21.3
5	54.5	21.5
10	55.1	21.7
15	55.4	21.8
20	55.8	22.0
25	56.1	22.1
30	56.3	22.2
35	56.5	22.2
40	56.7	22.3
45	56.9	22.4
50	57.1	22.5
55	57.3	22.6
60	57.5	22.6
65	57.7	22.7
70	57.9	22.8
75	58.2	22.9
80	58.5	23.0
85	58.8	23.2
90	59.2	23.3
95	59.6	23.5
97	60.0	23.6
98	60.3	23.7
99	61.7	24.3

Mean: 57.07 (0.02)[3] cm; 22.47 (0.01) in. Standard deviation: 1.58 (0.01) cm; 0.62 (0.00) in. Range: 51–62 cm; 20.08–24.41 in. V = 2.77 (0.03)%; N = 4056.

[1] Extracted from Hertzberg, Daniels and Churchill, '54, p. 71.

[2] Taken with subject sitting and tape passing above (but not including) the brow ridges, maximum value.

[3] Standard error.

All but those described by Chemical Warfare Service were based on conventional anthropometric dimensions taken by hand. Chemical Warfare Service used the so-called *Cartesian Faceometer* which located facial landmarks in space. Devices achieving comparable results were described by Garn, Hunt and Maranjian ('52), Hertzberg and Saul ('55) and Hertzberg, Dupertuis and Emanuel ('58). Although these techniques may be theoretically superior to the standard anthropometric approach in defining body shape, at this time it is more practical to take the conventional dimensions and have a sculptor translate these into representative head, face and body forms, using his trained eye to supply the details of surface shapes.

These earlier approaches to the presentation of anthropometric data in three-dimensional forms are inadequate for current problems. That this is so points up the need for continuing reappraisal of existing data and statistical analyses. In this connection, it must be realized that the nature of the equipment problem frequently dictates the design criteria selected for the form. Furthermore, there are limits to the extent to which the statistics may be manipulated and at the same time be integrated into non-distorted three-dimensional forms. This may be seen when attempting to sculpturally integrate components of a composite dimension such as stature or face length, where a constant (usually the mean) and some factor (usually some standard deviation or percentile) is employed. In such a case, the total for the components is greater than for the composite dimension itself, and this must be resolved by means of proportions or some other compromise which does not negate the intent of the form.

Before discussing the specific forms developed during our present effort, it will be useful at this point to clarify the concepts on which they are based. First, a *sizing system* is defined by the selection of *key dimensions* which serve as the basis for statistical analysis. It is important that these key dimensions be easily obtainable since they serve as fitting dimensions in the field. Next, *sizing programs* are established by dividing the ranges of the key dimensions into appropriate *intervals*, after which the desired values of the remaining important dimensions within each size are obtained. This is accomplished by treating each size as a separate sub-sample and by then computing the mean and the standard deviation within each size. Table 2 illustrates the case in which head circumference is the single key dimension selected as the basis for the sizing system. Attention is invited to the effect of a dimension having a low correlation coefficient with head circumference, i.e., head height (0.26), and one having a relatively high one, i.e., head length (0.67) (Churchill and Truett, '57). Lastly, after selecting a sizing program, the dimensions may be sculptured into a series of forms or fabricated into a series of pressure suits, oxygen masks, etc. In other words, a series

TABLE 2

Design ranges for the 6-size mean headforms and 6-size liner headforms[1]

Dimension	Size 1		2		3		4		5		6	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Head circumference	21.00	21.50	21.50	22.00	22.00	22.50	22.50	23.00	23.00	23.50	23.50	24.00
Head length	7.15	7.80	7.25	7.90	7.40	8.05	7.50	8.15	7.65	8.30	7.80	8.40
Head height	4.50	5.45	4.55	5.50	4.60	5.55	4.65	5.60	4.70	5.70	4.80	5.75

[1] Based on a table appearing in Zeigen, Alexander et al. ('60).

represents a concrete expression of a sizing program.

The forms considered in this paper concern the face, the head, and the body as a whole minus the head, hands and feet. They are developed, for the most part, on data obtained during the survey of the more than 4000 Air Force flying personnel previously referred to (Hertzberg, Daniels and Churchill, '54). Additional anthropometric data have been extracted from a photometric survey of some 2000 Air Force flying personnel made in 1957 (Seaford, '59). The successful applications of these forms and their associated data to previously unresolved sizing problems, tend to support their reliability.

Faceforms

Anyone who has observed pilots returning from extended flights, their faces deeply creased by the pressure of their oxygen masks, can appreciate the need for a soft, light-weight oxygen mask that does not need to be painful to be effective. For this reason, the Aerospace Medical Laboratory has long maintained a group of oxygen mask specialists.[2] These men designed a light-weight oxygen mask consisting basically of a deformable latex facepiece encased in a plastic cup for rigid support. After their effort to make this a one-size item failed, they approached the Anthropology Section for sizing design assistance (Emanuel, Alexander and Churchill, '59).

Two main problem areas had to be considered: first, to minimize discomfort, the mask had to rest on the bony bridge of the nose, and secondly, to insure a leak-proof fit, the mouth in both the relaxed and smiling positions had to be covered. For the first point, x-ray photographs[3] of 23 adult males revealed that the vertical distance between nasal root depression and the end of the nasal bone had a mean value of 0.76 inches and a standard deviation of 0.11 inches. Only about 2% of the population had values less than the mean minus two standard deviations or 0.54 inches. Therefore, by using 0.50-inch intervals for face

---

[2] Mr. Henry Seeler, Chief of the Special Projects Section, and his assistants.

[3] Dr. S. M. Garn of the Fels Research Institute, Yellow Springs, Ohio, kindly provided the x-ray photographs used.

TABLE 3

Design intervals for faceforms

Size	Face length	Lip length
Short-narrow	3.90–4.40	1.70–2.10
Short-wide	3.90–4.40	2.10–2.50
Regular-narrow	4.40–4.90	1.70–2.10
Regular-wide	4.40–4.90	2.10–2.50
Long-narrow	4.90–5.40	1.70–2.10
Long-wide	4.90–5.40	2.10–2.50

length (menton to nasal root depression) and designing the mask to the lower limit of this dimension, the upper end of the mask would fall somewhere on the nasal bone for all but a very few men in each size category. For the second point, the increase in lip length[4] during a broad smile was studied on a sample of 27 men, who had an average increase of 0.41 inches with a standard deviation of 0.20 inches. The mean plus two standard deviations gives us then an expected increase in lip length of about 0.80 inches. By dividing lip length into 0.4-inch intervals, a satisfactory fit seemed achievable.

On the basis of these data, a sizing system, having face length and lip length as the key dimensions, was established so as to theoretically include 96% of the 1950 sample. Table 3 shows that by using 0.5 inches for face length and 0.4 inches for lip length, a 6-size program results.

The actual design values of the 24 dimensions sculptured into the final faceforms depended on a number of special considerations (see table 4). As previously indicated, the lower limit of face length was desirable. The upper limit of the size interval for lip length was chosen since all other dimensions were taken with the lips in a relaxed or normal position; in working with the faceforms, the designer must consider the factor for increase of lip length during a smile. Next, the mean minus two standard deviations would insure a snug and, therefore, leakproof fit for the nasal root breadth. The same limits were selected for interocular diameter so as not to restrict visibility for personnel who are

---

[4] Dimensions referred to are described in Hertzberg, Daniels and Churchill ('54). Face length is the sum of nose length and menton-subnasale length. Check measurements made on a small sample showed only trivial differences between face length measured directly and the sum of menton-subnasale and nose length.

TABLE 4

Design limits for faceforms

Dimensions	Design limit
Face length	lower limit
Lip length	upper limit
Minimum frontal diameter	M[1] − 1 S.D.
Maximum frontal diameter	M − 1 S.D.
Bizygomatic diameter	M − 1 S.D.
Bitragion diameter	M − 1 S.D.
Interocular diameter	M − 2 S.D.
Biocular diameter	M − 1 S.D.
Nose length	[2]
Nose breadth	M + 2 S.D.
Nasal root breadth	M − 2 S.D.
Nose protrusion	M + 2 S.D.
Philtrum length	[2]
Menton-subnasale length	[2]
Lip-to-lip distance	[2]
Minimum frontal arc	M − 1 S.D.
Bitragion-minimum frontal arc	M − 1 S.D.
Bitragion-menton arc	M − 1 S.D.
Bitragion-submandibular arc	M − 1 S.D.
Bitragion-subnasale arc	M − 1 S.D.
Eye—tragion, vertical	mean difference
Nasal root—tragion, vertical	mean difference
External canthus—tragion, horizontal	mean difference
Nasal root—tragion, horizontal	mean difference

[1] M, mean.

[2] See discussion.

mall in this dimension. Since the mask nust be large enough to accommodate oth the width and protrusion of the nose, he mean plus two standard deviations apeared suitable for these dimensions. As reviously noted, a composite dimension nay require particular attention. Use of he lower limit of face length presents uch a situation, and proportional values vere computed for its component dimenions: nose length, philtrum length, lip-toip distance and menton-subnasale length. ach of these dimensions was expressed s a ratio of the mean face length for the articular size with the final design value eing determined by multiplying this ratio vith the design value of face length for he particular size. As an aid to the sculpor, the 4 vertical and horizontal relationships noted in table 4 were derived by subracting the various measurements. For ll other dimensions the design limits were he mean minus one standard deviation since the flexibility of the mask material permits coverage of persons with larger faces while, at the same time, the minimum values selected insure a tight seal for the narrow-faced individuals.

Figure 1 shows the resulting faceforms used for sizing the new light-weight oxygen mask. In an initial fit-test, 149 of 150 subjects could wear their indicated sizes, 99.3% without leakage at the desired simulated altitude of 41,000 feet.[5] Furthermore, as had been hoped for because of the deformability of the rubber, two of the wide sizes could be eliminated. Several hundred personnel have worn this oxygen mask during flights with excellent results, and it is soon to be placed in general Air Force use.

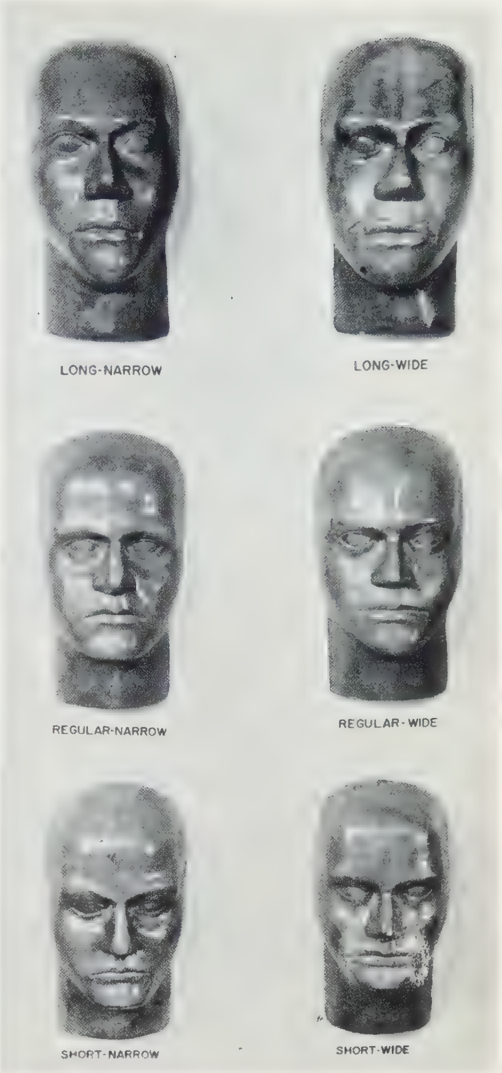


Fig. 1 Six-Size Faceform Series.

Headforms

The adequate sizing of hard-shelled helmets is an especially complex problem, if for two reasons only: first, the presence of the hard shell prevents the inherent adjustability found in, say, flexible oxygen masks or in pressure suits; and secondly, as Churchill and Truett ('57) so thoroughly report, conventional dimensions on the head have consistently low correlations with each other. In a new effort to resolve this situation an experimental sizing system for helmet design was developed using head circumference as the single key dimension (Zeigen, Alexander et al., '60). This dimension was selected for experimental trial over various other possible combinations for a number of reasons. Practical experience demonstrates that the simpler the fitting criteria, the more likely they will be followed. Because head circumference approximates the standard hat size, it appears capable of fulfilling this requirement of simplicity. No special measuring device is needed to take the dimension whereas a special caliper is required to measure head length and breadth, the pair of dimensions frequently used in sizing systems. Being a single key dimension, it has the advantage of minimizing procurement problems. From the theoretical viewpoint, moreover, little practical reduction in design values results in this case from using more than one key dimension. Lastly a single dimension lends itself much better to the elimination of alternate sizes should increased adjustability become available in the helmet support. In short, a single key dimension, if it can be made to serve, offers many solid advantages. Table 5 presents the intervals of head circumference for a 6-size program. When a one-inch interval of accommodation is possible, a three-size program can be derived by combining sizes 1 and 2, 3 and 4, and 5 and 6, as shown in table 6.

---

[5] Altitude at which the oxygen regulator begins to deliver positive pressure; a poor seal would result in an outward flow of oxygen.

Three specific sizing programs were developed as follows: a 6-size program designed to the mean, a three-size program designed to the mean, and a 6-size program designed for liner supports. The statistics developed for the first program serve as the basis for the other two programs. From the Six-Size Head Circumference Program, a series of headforms was sculptured to the mean values of the critical dimensions within each size interval of head circumference. The Three-Size Mean Headform Series was formed by eliminating headforms 1, 3 and 5. This elimination of alternate sizes resulted in some skewed mean values. In a reanalysis of the data for three intervals of head circumference, little practical difference was noted in absolute values between the original group of three (sizes 2, 4 and 6) and the reanalyzed group (combined sizes 1 and 2, sizes 3 and 4, and sizes 5 and 6). For the design values of each dimension within each size, the mean plus and minus 1.65 standard deviations was selected, giving a theoretical coverage from the 5th to the 95th percentiles. It is obvious that the designer must fabricate his helmet shells to cover the upper limits of these design values. Table 2 demonstrates the values so determined for two dimensions.

TABLE 5

Intervals of head circumference for a 6-size program

Size	Head circumference
1	21.0–21.5
2	21.5–22.0
3	22.0–22.5
4	22.5–23.0
5	23.0–23.5
6	23.5–24.0

TABLE 6

Intervals of head circumference for a three-size program

Size	Head circumference
1–2	21.0–22.0
3–4	22.0–23.0
5–6	23.0–24.0

While the mean headforms basically are meant to be used for the design of helmets having an adjustable sling or pad arrangement, those helmets having a liner-type support (for example, foam rubber) present somewhat different problems. These liners are most conveniently formed directly over the headforms with the shell being built over the liners—one shell accepting two or more liners. The mean headforms did not appear to provide adequate coverage if used for liner helmets. As a compromise, the mean plus one standard deviation was selected as the basis on which to sculpture a different series of headforms. This would provide coverage up to the 84th percentile for each dimension, even if there were no deformability of liner material. The practical differences between the 84th and the 95th percentiles on the head are small in absolute values, and it appeared reasonable to believe that the natural compressibility of the liner material could cover this difference without appreciably negating the protective or comfort qualities of the liner. Just as with the faceforms previously discussed, a number of variations from the basic approach were necessary and desirable. The design limits finally selected for the liner program appear in table 7.

In this case, the upper limit of head circumference was used for each size. To prevent anomalies in the headforms, regression equation values to these upper limits were derived for those dimensions

TABLE 7

Design limits for liner headforms

Dimensions	Design limit
Head circumference	upper limit
Head length	regression
Head breadth	regression
Minimum frontal diameter	M + 1.65 S.D.
Maximum frontal diameter	M + 1.65 S.D.
Bizygomatic diameter	regression
Bigonial diameter	M
Bitragion diameter	regression
Biocular diameter	M + 1 S.D.
Interocular diameter	M + 1 S.D.
Nasal root breadth	M + 1 S.D.
Face length	M + 1 S.D.
Menton-crinion length	M + 1 S.D.
Ear length	M + 1.65 S.D.
Ear breadth	M + 1.65 S.D.
Ear length above tragion	M + 1.65 S.D.
Ear protrusion	M + 1.65 S.D.
Head height	M + 1 S.D.
Menton projection	M + 1 S.D.
External canthus to wall	regression
Nasal root to wall	regression
Tragion to wall	regression
Sagittal arc	M + 1 S.D.
Bitragion-coronal arc	M + 1 S.D.
Minimum frontal arc	M + 1.65 S.D.
Bitragion-minimum frontal arc	M + 1.65 S.D.
Bitragion-crinion arc	M + 1 S.D.
Bitragion-menton arc	M
Bitragion-submandibular arc	M
Bitragion-posterior arc	M + 1 S.D.
Bitragion-inion arc	M + 1 S.D.
Neck circumference	M
Internal canthus—tragion	mean difference
Nasal root—tragion	mean difference

which form part of head circumference. In the forehead area, the mean plus 1.65 standard deviations was chosen, since Alexander and Hertzberg ('57) had demonstrated that larger dimensions are needed in this area to prevent discomfort and resultant pain. Maximum ear dimensions insure accommodation of all ears in the liner. Lastly, because the wearer of a pressurized helmet has extreme difficulty in turning his helmet unless his face is in contact with the liner, efforts were made to sculpture the mean values for the critical facial dimensions in order to minimize this problem.

In a preliminary fit-test of a helmet designed to the Three-Size Mean Head Circumference Program and its appropriate headform series, the 90 subjects tested were all accommodated in their appropriate helmet size.

Figures 2A, B and C represent the Three- and Six-Size Mean Headform Series, the former consisting of sizes 2, 4 and 6, and the latter of all the headforms shown.[6] Figures 3A, B, C and D demonstrate the differences between the mean headforms and liner headforms as illustrated by size 4 of each series; the former is distinguished by the letters HC and the latter by HCL. The black dots, which indicate dimension control points for the sculptor, include anatomical landmarks. The dot on the top of the mean headform is the point at which the bitragion-coronal arc intersects the mid-sagittal plane, with the true vertex being posterior to this point and about 0.1 inches higher; the same dot on the liner headform is at the true vertex.

These headforms are designed for helmet construction and should not be used for the design of equipment for the face. Certain dimensions in the forehead, eye and vertical facial areas were included only to insure helmet clearance of the eyes and face.

Bodyforms

More time and funds have been expended in perfecting adequate sizing systems for protective flying suits than for the two areas previously considered, despite their importance. Until recently, each manufacturer used his own commercial sizing techniques for his product, which made standardization of sizes very difficult. A study was initiated by the Anthropology Section to provide standard sizing techniques for all protective garments based on the known body size variability of the Air Force flying population. This study led to the formulation of the Height-Weight Sizing System (Emanuel, Alexander, Churchill and Truett, '59). It demonstrated that the two simple variables, height and weight, in general, showed the highest correlation with most other body dimensions important in clothing design; height correlated sufficiently well with most linear dimensions and weight did so with the lateral dimensions and girths. A number of sizing programs, varying from 4 to 20 sizes, were devised using height and weight as the key dimensions. Briefly stated, the Height-Weight Sizing

---

[6] Sculptured by Mr. Seth Velsey, Yellow Springs, Ohio.

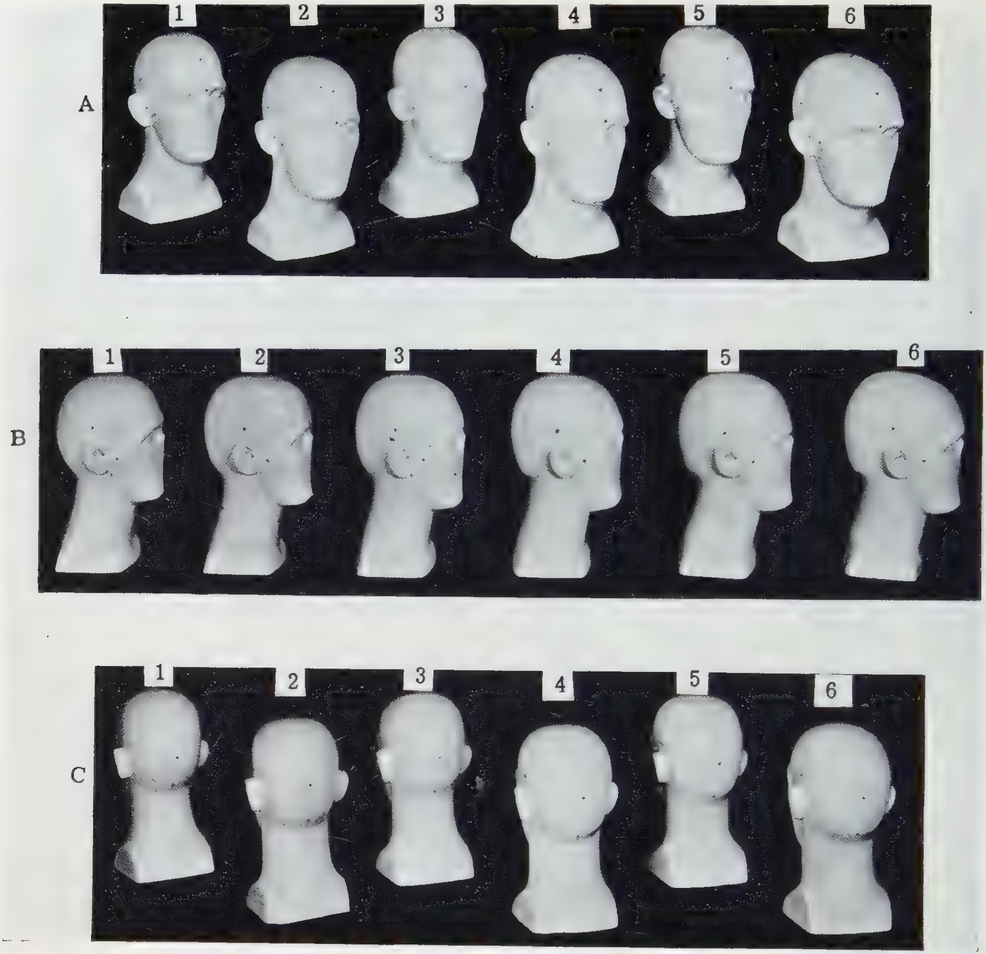


Fig. 2A, B, C Three- and Six-Size Mean Headform Series.

System results in carefully graded groups of sizes, each size accepting a definite known segment of the Air Force body-size distribution. To accomplish this, 1.5 standard deviations is added to and subtracted from the mean values of each of 56 dimensions within each size. At present, the Six-, Eight-, and Twelve-Size Programs appear to offer the greatest number of potential applications. Table 8 sets forth the height and weight intervals for the Eight-Size Program.

TABLE 8

Eight-size height-weight sizing program

Size	Weight	Height
Small regular	125–149	63.00–67.50
Small long	125–149	67.50–72.00
Medium regular	150–174	64.50–69.00
Medium long	150–174	69.00–73.50
Large regular	175–199	66.00–70.50
Large long	175–199	70.50–75.00
X-large regular	200–224	67.50–72.00
X-large long	200–224	72.00–76.50

The Height-Weight System was introduced into several types of close-fitting garments for which previous sizing approaches had been ineffective. The resized articles, on the other hand, fit about 95% of 225 flying personnel in their indicated sizes; an additional two to three per cent could wear the next larger or smaller size. Although this system has been objectively proven, the data incorporated into three items were interpreted on each occasion

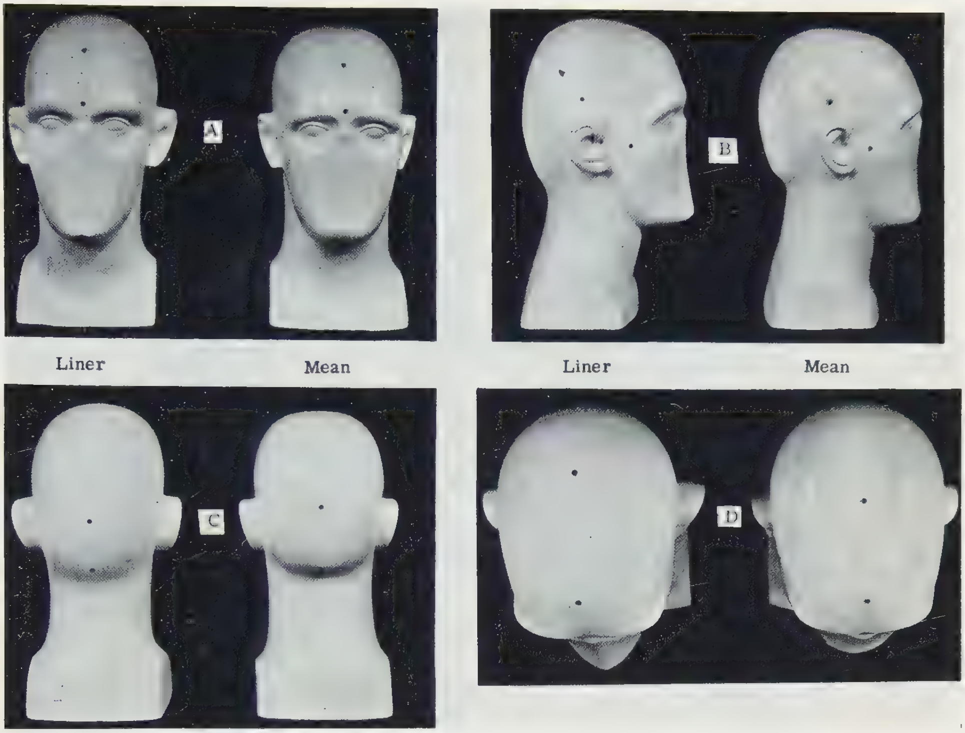


Fig. 3A, B, C, D Comparison Between Sizes 4 of the Mean and Liner Headform Series.

for the different manufacturers, which took a considerable amount of time. Furthermore, manufacturers' representatives, having different backgrounds, understood the data and interpretations differently. Standard tailor manikins, when used for design and fabrication, merely confused the issue, since whatever data which may have been incorporated into them through trial and error in no way approached the anthropometric data comprising the various height-weight programs. Therefore, to achieve reasonable standardization of these variables, height-weight bodyforms were envisioned as an aid in reducing the complexities of applying anthropometric data and in eliminating the need for repeated interpretation by Air Force anthropologists. Such forms would be minus head, feet and hands, as the Height-Weight System does not provide for these body segments.

For the first experimental three-dimensional representations of the body, the Eight-Size Height-Weight Program was selected since this appears to have greater potentional application than any other program (Alexander and McConville, in preparation). These forms are in rigid, standing position, with no provisions for movable segments. After resolving the problems concerned with building these bodyforms, more advanced ones with movable arms and legs are planned. The rigid forms are being built primarily to the upper limit for each dimension, that is, to the mean plus 1.5 standard deviations. In doing so, the problems which arise with a composite dimension appeared in several instances such as in attempting to integrate cervical height and vertical trunk circumference. As it turned out, the compromise taken actually enhances the ease with which the forms may be used by the designer. In the majority of the close-fitting protective suits made to date, the major consideration has been given to the torso area since this must conform to the body whereas there is no special disadvantage if the sleeves or legs of the garments are not of optimum

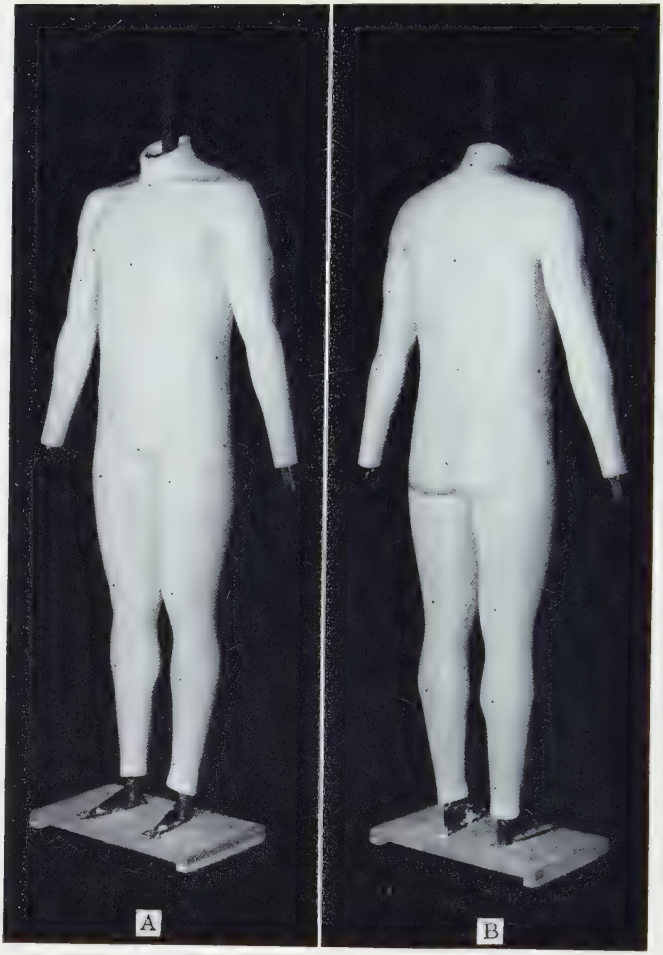


Fig. 4A, B Medium-Regular Bodyform, Eight-Size Height-Weight Series.

length. Therefore, the dimensions included in the torso were held to the mean plus 1.5 standard deviations, while those for the lengths of the legs and of the elbow location were sculptured to the mean values. This approach for the limbs provides the designer with a more exact position for the point where the arm and leg joints must bend. Not only would it be impossible to build the leg segments to the mean plus 1.5 standard deviations and still maintain the total body dimensions, but it would also be a handicap to the designer who would then have to introduce some factor for the joint breakpoints. The end result is that the manufacturer, in using these forms, would know the nude values of the maximum figure to be clothed in any given size. At the same time, he must be aware of the lower design values for each dimension to insure that the smallest person to wear each size would not be discommoded. Figure 4 reflects the medium-regular size of the Eight-Size Height-Weight Series.[6]

SUMMARY

The anthropometric data gathered by the physical anthropologist may be used to design personal protective equipment. Since these data must be interpreted for the designer and engineer prior to their application to practical problems, the Anthropology Section, Aerospace Medical Laboratory, develops approaches to objectify these ends. One recognized method is the presentation of each dimension under its mean, standard deviation and percentiles. This approach is generally acceptable for workspace situations requiring gross measurements. On the other hand, considerable confusion exists among designers in handling anthropometric data for close-fitting protective equipment, e.g., pressure suits, oxygen masks and helmets. The primary approach to this problem is to translate the anthropometric data into representative three-dimensional forms. Previous efforts along these lines are inadequate for present problems. In all of the current approaches, *statistical sizing systems* are set up on the basis of *key dimensions*, which serve as fitting dimensions in the field; *sizing programs*, including minimum and maximum design values, are established by dividing the key dimensions into appropriate size intervals; and a *series* of forms are sculptured to a particular sizing program. Forms have been developed for the face (key dimensions are face length and lip length); head (using head circumference as a single key dimension); and the body (based on the key dimensions height and weight). Oxygen masks, helmets and high-altitude protective clothing designed to the reanalyzed data and to the resultant forms have eliminated a number of critical sizing problems in the Air Force.

---

[6] See footnote 6, p. 153.

LITERATURE CITED

Alexander, M., and H. T. E. Hertzberg 1957 Comfort evaluation of a form-fitting high altitude helmet. WADC Technical Report 56–404, Wright Air Development Center, Wright-Patterson AFB, Ohio.

Alexander, M., and J. McConville USAF height-weight sizing manikins. In preparation. Wright Air Development Division, Wright-Patterson AFB, Ohio.

Chemical Warfare Service 1945 C. W. S. anthropometric data on faces and heads. C. W. S. Pamphlet MIT 1, Chemical Warfare Service Development Laboratory, MIT, Cambridge, Mass.

Churchill, E., and B. Truett 1957 Metrical relations among dimensions of the head and face. WADC Technical Report 56–621, Wright Air Development Center, Wright-Patterson AFB, Ohio.

Cole, C. A., Jr., R. D. Jordan, L. G. Derrick, J. F. Quinlan and M. D. Inskeep 1958 Military helmet design. Research Project NM81 01 09.1, Naval Medical Field Research Laboratory, Camp Lejeune, N. C.

Emanuel, I., M. Alexander, E. Churchill and B. Truett 1959 A height-weight sizing system for flight clothing. WADC Technical Report 56–365, Wright Air Development Center, Wright-Patterson AFB, Ohio.

Emanuel, I., M. Alexander and E. Churchill 1959 Anthropometric sizing and fit test of the MC-1 oral-nasal oxygen mask. WADC Technical Report 58–505, Wright Air Development Center, Wright-Patterson AFB, Ohio.

Garn, S. M., E. E. Hunt, Jr. and G. Maranjian 1952 Forsyth rapid reading faceometer and data for headform design. Final Report, Part II, Contract No. DA 18–108–CML–2829, Forsyth Dental Infirmary for Children, Boston, Mass.

Hertzberg, H. T. E. 1960 Dynamic anthropometry of working positions. Human Factors, *2:* 147–155.

Hertzberg, H. T. E., and F. P. Saul 1955 The Lange-USAF Contourometer, a new type of measuring instrument. Paper presented at the 24th Annual Meeting of the AAPA, Philadelphia, Penna.

Hertzberg, H. T. E., C. W. Dupertuis and I. Emanuel 1958 Stereophotogrammetry as an anthropometric tool. WADC Technical Report 58–67, Wright Air Development Center, Wright-Patterson AFB, Ohio.

Hertzberg, H. T. E., G. S. Daniels and E. Churchill 1954 Anthropometry of flying personnel —1950. WADC Technical Report 52–321, Wright Air Development Center, Wright-Patterson AFB, Ohio.

Koepnick, R. C., and R. S. Benton 1944 Head size standards. Memorandum Report ENG–49–695–32R, AAF Materiel Center, Engineering Division, Aero Medical Laboratory, Wright Field, Ohio.

Randall, F. E. 1943 Articulate plastic manikin standards. Memorandum Report ENG–49–695–28, AAF Materiel Command, Engineering Division, Aero Medical Laboratory, Wright Field, Ohio.

Randall, F. E., and A. Damon 1942 Facial types among aviation cadets. Memorandum Report EXP–M–49–695–15, AAF Materiel Center, Engineering Division, Aero Medical Laboratory, Wright Field, Ohio.

Saul, F. P., and B. Truett An anthropometric statistical sizing system for rigid shell helmets. Unpublished Mss., Wright Air Development Center, Wright-Patterson AFB, Ohio.

Seaford, H. W., Jr. 1959 Comments on the photometric system. Am. J. Phys. Anthrop., *n.s. 17:* 83–85.

Zeigen, R. S., M. Alexander, I. Emanuel, E. Churchill and S. Velsey 1960 A head circumference sizing system for helmet design: including three-dimensional presentations of anthropometric data. WADD TR 60–631, Wright Air Development Division, Wright-Patterson AFB, Ohio.

Stature and Build of Hawaii-Born Youth of Japanese Ancestry[1]

CAREY D. MILLER
Foods and Nutrition Department, University of Hawaii Agricultural Experiment Station, Honolulu, Hawaii

It is now a generally accepted fact that, although the potential stature of any individual may be governed by heredity, environmental factors play an important role in determining the stature which is actually achieved. A number of studies (Bowles, '32; Boyne and Leitch, '54; Ito, '42; Lasker, '46; Shapiro, '39; Spier, '29) of various racial groups have indicated a marked trend toward increasing heights in the younger generations. Many of these reports have also included studies of other physical measurements which show changes in bodily form.

Special reference is here made to studies on Japanese. Spier ('29) found boys and girls of Japanese ancestry in Seattle to be taller than children of the same ages in Japan; while Ito ('42), who confined his studies to Japanese women in the United States and Japan, found those in the United States developed most rapidly, those in Japan were the slowest, and the migrant groups fell between the means for the first two groups. More recently Greulich ('57) has compared the growth and development of American-born and native Japanese children from 5 to 18 years of age and found the California Japanese children to be taller, heavier, and more advanced skeletally than the native Japanese. Data from Shapiro's ('39) study of Japanese in Hawaii and their relatives in Japan, or people from the same area as the migrants, will later be compared with our results.

In 1944 the author (Miller, '45) reported a study of the stature of 445 high school girls of Japanese ancestry, 15 to 18 years of age, and their mothers. The mean heights (154.0 to 155.7 cm) of these girls born in Hawaii in the different age groups were from 4.2 to 5.1 cm greater than the mean heights of the mothers. But it was noted that the mean stature of all the girls (154.9 cm) was considerably less than that of 666 girls 15 to 18 years of age measured at the University of Iowa in 1936 whose mean height was 161.1 cm (Boynton, '36).

The original purpose of the study here reported was to examine some cooperative University students (all citizens of the United States of America born in Hawaii), to appraise the condition of their teeth, to make certain limited physical measurements, supported by photographs in the near nude, to obtain a history of past dietary habits, and to learn, if possible, any relationship between diet, teeth, and stature.

Students of Japanese ancestry were chosen for study because they represent a large ethnic group in Hawaii and because the author believed that over a period of almost 30 years, she had noted an increase in their stature but no improvement or deterioration in the state of the teeth.

The study of the teeth already published (Miller et al., '52) showed a high dental caries rate of 17 DMF per person by oral clinical examination and 19 DMF per person when the defective teeth detectable by x-ray were added, plus third molars only if filled or decayed.

This paper presents background material regarding the subjects, procedures used, data on heights and weights, and comparisons with published results. The paper which follows will discuss the somatotypes of these subjects.

MATERIALS AND METHODS

Subjects

The subjects were recruited largely through the assistance of the instructors

---

[1] Published with the approval of the Director of the Hawaii Agricultural Experiment Station as technical paper no. 461.

in the physical education classes at the University of Hawaii. Some of the women were majors in Home Economics and a few volunteered because their friends were subjects. A few of the students who began the study failed to cooperate fully, but complete data on body build was obtained for 104 men and 104 women.

Since complete cooperation and considerable time were required to obtain the necessary information, the subjects were volunteers rather than chosen by any special method of selection. It is believed that they represent a good cross-section of the students of Japanese ancestry attending the University, based both on the alphabetical list of names, the islands on which they were born, and the professions of their fathers.

The subjects came from all the larger islands of the Hawaii chain. Table 1 gives the distribution of subjects by islands compared with the percentage distribution of the total island population. As not all the subjects had always lived in the same place, table 1 shows the place of residence for all or most of their lives. This distribution between islands is similar to that for the total population, in that a larger percentage of the students lived on the island of Oahu than on the other islands. However, it does not follow the general distribution closely as in most cases a larger per cent, especially of the men, came from the outer islands. Although no men appear to have come from the island of Lanai, one was born and lived there almost half his life before moving to Oahu and two of the women came from that island.

The occupations of the fathers (or previous occupation if not living at the time of the study) shown in table 2 indicate a rather wide range of pursuits with only a few in the professional class.

All parents were Japanese, born abroad or in Hawaii. Birthplaces for the parents

TABLE 1

Subjects' place of residence for all or most of life compared with island population

Island	Subjects		Island population 1950 census (both sexes)
	Men	Women	
	%	%	%
Oahu			
Urban	38.5	51.9	57.4
Rural	7.7	10.6	13.2
Hawaii	22.1	17.3	13.7
Kauai	18.3	10.6	6.0
Maui	12.5	6.7	8.0
Molokai	1.0	1.0	1.0
Lanai		1.9	0.6
Total	100.1	100.0	99.9
Number	104	104	499,794

TABLE 2

Occupations of fathers of the subjects

	Men	Women
Clerical, general store and other small business	18	28
Agricultural pursuits (farmers, gardeners, field laborers, nurserymen)	34	20
Mechanical pursuits (mechanics, plumbers, electricians, tractor operators, etc.)	11	20
Building pursuits (carpenters, contractors, painters)	9	12
Miscellaneous (a wide variety of occupations, e.g., teacher, commercial artist, tailor, laboratory analyst, landlord, chef, foremen, etc.)	32	24

of the male subjects were as follows: both parents born in Japan, including Okinawa, 54.81%; both parents born in Hawaii, 19.23%; one parent born in Japan and one in Hawaii, 25.96%. For the female subjects, the birthplaces of the parents were: both parents born in Japan, including Okinawa, 50.00%; both parents born in Hawaii, 19.23%; one parent born in Japan and one in Hawaii, 30.77%.

No effort was made to distinguish between those students whose parents came from Okinawa and those who came from Japan proper. Judging from the surnames of the students, approximately 8% of the men had surnames that could be either Japanese or Okinawan in origin, 14.4% had surnames that would almost certainly indicate that the fathers were of Okinawan origin. For the girls 15% of the surnames might be either Japanese or Okinawan and 11.5% were quite certainly of Okinawan origin. No similar information regarding the mothers' surnames was obtained.

All the women were studied between March 2, 1948, and October 18, 1948, and the men from November 5, 1948, to May 17, 1949.

Procedure

The subjects came to the laboratory and conference room according to a prearranged schedule. Approximately an hour was required to obtain personal data relating to birthdate, place of birth, residence, parents' background, and dietary history. Then the subjects were weighed, measured and photographed. Each was scheduled for an oral dental examination on the campus, and for x-rays of teeth and hand by a professional x-ray specialist.

Body weights were determined by using a spring scale that was checked in the University Physics Department with accurate weights. Within the range of the students' weights (80 to 190 pounds), the deviations of this scale from the true weights were found to be 0 to ¼ pound. Although greater accuracy might have been desirable, the diurnal variations in weight and the effect of humidity make it unlikely that a better scale would have added greatly to the accuracy of the weights. The women were weighed with only a piece of clean sheet as a sarong; the men wore shorts or athletic belts.

Special measuring devices were built for the purpose of determining standing and sitting heights. A one-inch board 15″ × 15″ formed a small platform to which an upright board was attached and firmly fastened to the wall. On the upright, slightly to one side, a paper centimeter scale was carefully pasted. The subject stood on the platform and was instructed to stand erect with eyes straight ahead and chin drawn in. A right-angled board with handle, and a cleat to catch the edge of the upright, was lowered until it touched the crown of the head. This measurement was repeated several times to check the stature.

The "chair" for sitting heights had a seat 46 cm from the floor with a straight flat back on which a paper scale was pasted slightly to one side. All female subjects were measured with the feet on the rung of a stool so that the knees were slightly higher than the hips. The sitting heights of the male subjects were measured in the same manner, but also with the thighs at right angles to the trunk and knees bent in the natural position as described by Hrdlička ('39) for the International Standards. In both cases the sacral region and the shoulder blades were in contact with the straight back and the head was held erect, eyes straight ahead, and measurements taken as for height. (The slight differences between measurements obtained by these two methods will be discussed later.)

It was not possible to obtain heights and weights of all like-sexed parents. In a few cases the parent was not living. If the parents could be reached and were willing to be weighed or measured, the values were obtained by the author. In some cases the sons or daughters were asked to record the difference in the stature of the like-sexed parent in the following manner. A piece of paper was firmly affixed to some flat surface like a door jamb with thumb tacks or tape. By using a book with firm back, the heights of the parent and offspring were marked clearly on the paper. This paper was brought to the author who estimated the parent's height from the son's or daughter's height that had been carefully determined in the laboratory.

Photographs

The subject stood on a platform 20″ from the floor against a black background which was 43″ × 71″ in a white frame. A frame with lumalights was placed about 50″ from the background. This frame, 89″ high and 51″ wide, had 46½″ lumalight globes at the top and bottom and on each side were two globes, one 46½″ and one 22″ in length.

An Eastman View Camera no. 2D (5″ × 7″) was used so that the center of the lens was about 54″ from the floor. The distance from lens to subject was 72 ± 3 inches.

To obtain the cooperation of the students, it was necessary to conceal the face. Since the photographs taken to show front, back, and side views were used for the somatotype ratings, they are included in the second paper.

RESULTS AND DISCUSSION

The ages of the subjects ranged from 18 to 23 years with a mean of 19.31 for the men and 19.58 for the women. The men of ages 18 to 19 may not have reached their full stature and may have grown a little after they were measured if they follow the pattern of Caucasians measured in the Harvard study (Shuttleworth, '39). Since all the women were 18 years of age or older they had doubtless achieved their full stature, judging from the Iowa and Harvard studies of girls 15 to 18 or 19 years of age, although the university and college women studied in the North Central Region showed small progressive increases in height and weight for ages 17, 18, and 19 (Donelson et al., '40).

The x-rays of the hands showed complete skeletal maturity when compared with Greulich and Pyle's radiographic standards (Greulich and Pyle, '50) except for one female subject, age 20, and one male subject, age 19, for which the epiphyses of the radius did not show complete closure.

The data on heights and weights of all subjects are presented in the Appendix and summarized in tables 3 and 4. A separate tabulation is given for those students whose fathers and mothers were measured and weighed, in order to make the data comparable. However, in the matter of stature, the mean for 80 men whose fathers were measured, differs from that of the total number (104) by only 0.6 cm, equivalent to the standard error of the mean. The 83 daughters whose mothers were measured had a mean height only 0.3 cm less than that for the 104 subjects.

The frequency distribution of heights (table 3), the range of 33 cm in stature, and the standard deviation, all indicate a wide variation in heights of the 104 men. There is an even wider range in weights. The variations in the heights and weights of the fathers are similar. The mean height of the 80 sons is 7 cm greater than that of the fathers; 90% of the sons were taller than the fathers.

Compared with the recent data of Sturzebecker ('50) for men 18 and 19 years of age measured in certain colleges and universities in Pennsylvania and Delaware, the University of Hawaii students of Japanese ancestry are about 10 cm shorter.

Compared with Shapiro's data on 188 men of Japanese ancestry born in Hawaii and measured in 1931–32, the mean stature of the men in this study is 4.0 cm greater (table 5).

The women also showed a wide range in stature of 26 cm, only 4 cm short of that shown by the men, but the frequency distribution table for heights (table 3) shows a narrower range than that for the men. Their increase in height (5.7 cm) over that of the mothers as might be expected is less than the difference in the mean statures for the fathers and sons, although 86% of the daughters were taller than their mothers.

Shapiro's data on stature for women summarized in table 5 show that in 1931–32 females in Japan were shorter than the immigrants and the immigrants were shorter than those born in Hawaii. Our subjects were 5.5 cm taller than his Hawaii-born females, a greater increase than shown for the men above.

The stature of the University of Hawaii Japanese-American women is less than that of young women of college age measured by a number of investigators on the United States mainland. The women measured in state universities and colleges of 5 states of the North Central Region were chosen from among the general stu-

TABLE 3

Frequency distribution of heights and weights

Cm	Heights				Pounds	Weights			
	Sons	Fathers	Daughters	Mothers		Sons	Fathers	Daughters	Mothers
137.6–140.5				2	79.6– 85.5			2	2
140.6–143.5		2	1	8	85.6– 91.5		4	4	5
143.6–146.5			2	16	91.6– 97.5		2	19	5
146.6–149.5		2	5	17	97.6–103.5	4	1	12	8
149.6–152.5	1	5	12	16	103.6–109.5	2	1	20	9
152.6–155.5	2	5	33	13	109.6–115.5	9	5	16	9
155.6–158.5	6	15	31	6	115.6–121.5	15	4	12	12
158.6–161.5	9	19	11	5	121.6–127.5	18	4	8	8
161.6–164.5	18	9	6		127.6–133.5	16	6	4	4
164.6–167.5	24	14	1		133.6–139.5	16	4	1	6
167.6–170.5	21	5	2		139.6–145.5	12	6	4	4
170.6–173.5	11	3			145.6–151.5	5	4	1	3
173.6–176.5	7	1			151.6–157.5				
176.6–179.5	3				157.6–163.5	2		1	2
179.6–182.5	1				163.6–169.5	2	1		
182.6–185.5	1				169.6–175.5	1			
					175.6–181.5	1			
					181.6–187.5				1
					187.6–193.5				
					193.6–199.5	1			

TABLE 4

Heights and weights of subjects and like-sexed parents

	Heights					Weights				
	No.	Range	Mean	S.D.	S.E.	No.	Range	Mean	S.D.	S.E.
		cm	*cm*				*lbs.*	*lbs.*		
Men										
All sons studied	104	152.4–185.5	166.8	5.9	0.6	104	100.5–197.0	130.8	16.1	1.6
Sons	80	152.4–185.5	167.4	6.1	0.7	42	103.5–176.0	130.8	14.0	2.2
Fathers	80	141.6–173.8	160.4	6.3	0.7	42	88 –168	124.0	19.5	3.0
Women										
All daughters studied	104	143.0–169.1	155.7	4.4	0.4	104	82.5–161.5	109.9	14.7	1.4
Daughters	83	143.0–168.5	155.4	4.4	0.5	78	82.5–150.5	109.3	13.6	1.5
Mothers	83	139.3–160.7	149.7	5.1	0.6	78	81 –183	116.7	19.3	2.2

TABLE 5

Comparison of Shapiro's data on Japanese subjects with data on University of Hawaii students

	Shapiro's data			This study
	Sedentes	Immigrants	Hawaii-born	U. H. students
	Men			
Age	20–64	20–64	20–49	18–23
No. of heights	171	178	188	104
Mean stature (cm)	158.4	158.7	162.8	166.8
Mean sitting ht. (cm)	84.5	83.1	85.5	90.7
Mean total leg length (cm)	73.8	75.6	77.4	76.1
No. of weights	143	174	185	104
Mean weight (lbs.)	119.8	124.0	127.4	130.8
	Women			
Age	20–64	20–64	20–49	18–23
No. of heights	91	93	91	104
Mean stature (cm)	146.0	148.5	150.2	155.7
Mean sitting ht. (cm)	78.9	78.8	78.9	84.7[1]
Mean total leg length (cm)	67.1	70.2	71.3	70.9[1]
No. of weights	71	78	86	104
Mean weight (lbs.)	104.4	113.0	103.3	109.9

[1] Mean of 103 women.

dent body because they were in good health (Donelson et al., '40). The mean for those 18 years old was 163.6 cm and for 19 years, 164.0 cm. Sturzebecker ('50) reported a mean height of 162.80 cm for 150 young women 19 years of age in eastern schools and colleges. A large study of more than 10,000 women undertaken by the United States Department of Agriculture with the purpose of establishing standard measurements for pattern makers (O'Brien and Shelton, '41) gives the mean height of native-born women 18 to 29 years as 161.5 cm. These data include only a very small percentage of university and college women. The Metropolitan Life Insurance Company Statistical Bulletin ('42) regards the U.S.D.A. averages as too low. However, the U.S.D.A. figure given above is only 1.3 cm less than Sturzebecker's figure for 19-year-olds and 2.5 cm less than the North Central States means. When one considers that university and college students usually represent a select group that has had relatively greater economic and social advantages, the magnitude of the differences are not great.

The mean for our female subjects of 155.7 cm is 5.8 to 8.3 cm less than the data for heights of the Caucasian-American groups cited above, and since only 9 of the University of Hawaii women of Japanese ancestry equal or exceed the U.S.D.A. and Sturzebecker means, it is obvious that most of them are of small stature when compared with Caucasian-Americans.

"Leg lengths" (table 5) were derived by subtracting the sitting heights from the standing heights for each subject. As mentioned on page 161 sitting heights of the women were taken as recommended for "stem length" by Dreyer ('19) with the knees elevated by placing the feet on the rung of a stool, to position the upper leg at about a 45° angle with the trunk. For the men, the stem lengths were taken in the same manner, but sitting heights were also taken on a "chair" as recommended by Hrdlička (quoting the Geneva Agreement) ('39) with the knees flexed, the feet on the floor and the lower leg at right angles to the upper leg. The differences in these two measurements for the men were usually less than 0.4 cm. It is therefore believed that the figures for stem length of the women are essentially those of sitting height.

The increase in stature of these young people over those measured by Shapiro was not the result of an increase in leg length as was anticipated (table 5). Exposure to sunshine in Hawaii should have promoted the formation of ample vitamin D which is generally accepted as causing an increase in leg length (Sherman, '52). Trunk length as such was not determined, but sitting heights, which are closely related to trunk lengths, showed for both our male and female subjects a marked increase over the values reported by Shapiro (table 5).

It is interesting to compare our figures for stature with the data in a recent publication from Japan (Ministry of Health and Welfare, '57) which proposes, for age 19 years, standards of 161.8 cm for males and 151.0 cm for females for both urban and rural areas. Most of the University of Hawaii men and women exceeded these standards as may be noted from tables 3 and 4. Some of the average heights by years given separately for urban and rural areas of Japan exceed their recommended standards. The greatest average heights for men 19 years of age were in 1955, 163.8 cm in urban and 162.7 cm in rural areas. The greatest average heights for women 19 years of age were in 1956, 152.4 cm in urban and 150.9 cm in rural areas. (Data are given by years from 1947 to 1956 inclusive and from birth to 71 years.)

Greulich's data ('57) for American-born Japanese show boys of 18 years to have a mean stature of 169.2 cm which exceeds the Hawaii mean for 19-year-old boys by 2.4 cm. However, his California-born girls of 18 years had a mean stature of 154.2 cm compared with the mean for our 19-year-old girls of 155.7 cm.

A number of factors have probably contributed to the increased stature of these young Americans of Japanese ancestry compared to their parents, including climate and medical care, but food is believed by the author to be the chief cause. Changes in food habits will be discussed in a forthcoming paper on the dietary history of these subjects.

The data reported here suggest the desirability of making more extensive height-weight studies on people of Japanese ancestry in Hawaii at 10-year intervals in order to follow the changes resulting from environment in this area.

Since the efforts of nutritionists to improve the quality of the diet of all people (especially through infancy, childhood, and youth) and thus improve general health and physical fitness is also resulting in increasing the size of people everywhere, it seems pertinent to inquire whether this continuous increase in stature is really desirable. Do people of greater stature show superior health, longer productive lives, and greater mental achievements?

Certainly the problems of providing an adequate food supply are increased when it is necessary to furnish calories and other nutrients for men of 6 feet and more compared with men of moderate stature.

While there is no lack of data to prove the general association of a greater and earlier mortality for those overweight compared with those of more average weight, the data relating stature and mortality and physical fitness are relatively sparse and somewhat conflicting.

The Metropolitan Life Insurance Company (Statistical Bull., '37) made a study of 20,000 tall men (6 feet 2 inches in height and over) and concluded that they had a practically normal mortality and that most tall men are physically normal.

Seltzer ('46) after studying 300 aviation cadets and several groups of college students, principally freshmen at Harvard College, concluded that there is a "virtual absence of relationship between stature, weight (and certain other measurements) with physical fitness."

Dr. Morrell L. Isley ('40) as a result of studying 358 college men stated "the taller the man the more apt is he to be ill" and "the heavier the man, the more apt is he to become ill." Nevertheless, he concluded there was no association between physical fitness and height.

The effects of certain endocrine glands on extremes of stature are well recognized but a discussion of these factors is outside the scope of this paper.

The problem of whether or not there is any relationship between intelligence and height and intelligence and weight has intrigued people for many years. Almost a 100 years ago Sir Francis Galton (1869) came to the conclusion that men of genius tend to be above average in height and weight. As a result of their study of 490 De Pauw University freshman, Middleton and Moffett ('40) point out that while there are slight positive relationships between intelligence and height or weight, they are so small as not to be useful as a means for predicting the probable intelligence level of any given individual. They state further that "perhaps the important point to emphasize is the fact that physical status and intellectual status are largely independent of each other."

Since there appear to be no advantages accruing from the general increase in stature, the challenge for the future is to learn how to provide all food nutrients in the proper quantities needed for optimum health and yet keep the size of the human frame within reasonable limits.

SUMMARY

Japanese-Americans (Hawaii-born students of Japanese ancestry) at the University of Hawaii who volunteered to cooperate were the subjects for a study of heights, sitting heights, and weights. Measurements were made on 104 males, average age 19.31 years, and 80 fathers; and 104 females, average age 19.58 years, and 83 mothers; 90% of the men and 86% of the women were taller than their like-sexed parents.

The means for stature of the Japanese-American men and women exceeded those of Japanese ancestry previously measured in Hawaii and those recently measured in Japan but were considerably smaller than the means for similar groups of Caucasian-Americans studied on the mainland U.S.A.

Some aspects of the problem of the general increase in stature of men and women are discussed.

ACKNOWLEDGMENTS

The author is indebted to Dr. Walter M. Bortz (at present resident in Medicine, Charity Hospital, New Orleans, La.) for evaluating the hand x-rays.

The technical assistance of Mrs. Mildred Ige, laboratory aide, with tabulation and calculation of the data is gratefully acknowledged.

LITERATURE CITED

Bowles, G. T. 1932 New Types of Old Americans at Harvard. Harvard University Press, Cambridge, Mass., 144 pp.

Boyne, A. W., and I. Leitch 1954 Secular change in the height of British adults. Nutr. Abstr. Rev., *24:* 255–269.

Boynton, B. 1936 The physical growth of girls. A study of the rhythm of physical growth from anthropometric measurements on girls between birth and 18 years. University of Iowa Studies in Child Welfare, *121:* no. 4.

Donelson, E. G., M. A. Ohlson, B. Kunerth, M. B. Patton and G. M. Kinsman 1940 Anthropometric data on college women of the middle states. Am. J. Phys. Anthrop., *27:* 319–332.

Dreyer, G. 1919 Investigations on the normal vital capacity of man and its relation to the size of the body. Lancet, *197:* 227–234.

Galton, F. 1869 Hereditary Genius. Reprinted from the first edition, 1869, by Macmillan & Co., Ltd., London, 1925, 379 pp. (p. 321).

Greulich, W. W. 1957 A comparison of the physical growth and development of American-born and native Japanese children. Am. J. Phys. Anthrop., *15:* 489–515.

Greulich, W. W., and S. I. Pyle 1950 Radiographic Atlas of Skeletal Development of the Hand and Wrist. Stanford University Press, Stanford, California.

Hrdlička, Aleš 1939 Practical Anthropometry. The Wistar Institute of Anatomy and Biology, Philadelphia, Pa., 231 pp.

Isley, M. L. 1940 Study of correlations on measurements of men students at Pomona College. Res. Quart., *11:* 115–120.

Ito, P. A. 1942 Comparative biometrical study of physique of Japanese women born and reared under different environments. Human Biol., *14:* 279–351.

Lasker, G. W. 1946 Migration and physical differentiation. A comparison of immigrant with American-born Chinese. Am. J. Phys. Anthrop., n.s., *4:* 273–300.

Metropolitan Life Insurance Company. 1937 The longevity of very tall men. Statistical Bull., *18:* 1–2.

——— 1942 The stature of American women. Ibid., *23:* 9–10.

Middleton, W. C., and D. C. Moffett 1940 The relation of height and weight measurements to intelligence and to dominance-submission among a group of college freshman. Res. Quart., *11:* 53–59.

Miller, C. D. 1945 Some aspects of growth and food needs. Presidential address 1944. Proceedings of the Hawaiian Academy of Science. 19th and 20th annual meetings 1943–1945. University of Hawaii, Honolulu, Hawaii, p. 7., 16 pp.

Miller, C. D., A. C. Bickerton and G. L. Parke 1952 Dental caries in 205 students of Japanese ancestry at the University of Hawaii. Hawaii Med. J., *11:* 216–220.

Ministry of Health and Welfare, Tokyo 1957 (Nutrition Section, Bureau of Public Health.) Nutrition in Japan, 1957, pp. 10–17.

O'Brien, R., and W. C. Shelton 1941 Women's measurements for garment and pattern construction. Misc. Publ. no. 454, U. S. Department of Agriculture in cooperation with the Work Projects Administration.

Seltzer, C. 1946 Anthropometric characteristics and physical fitness. Res. Quart., *17:* 10–20.

Shapiro, H. L. 1939 Migration and Environment. A study of the physical characteristics of the Japanese immigrants to Hawaii and the effects of environment on their descendants. Oxford University Press, London, 594 pp.

herman, H. C. 1952 Chemistry of Food and Nutrition, 8th ed. The Macmillan Co., New York, 721 pp.

huttleworth, F. K. 1939 The physical and mental growth of girls and boys age 6 to 19 in relation to age at maximum growth. Monograph, Soc. Res. Child Devel., *4:* no. 3.

pier, L. 1929 Growth of Japanese children born in America and in Japan. University of Washington Publications in Anthropology, *3:* 1–30. University of Washington Press, Seattle.

Sturzebecker, R. L. 1950 Sex differences in anthropometric measures and ratios of college students aged 18 to 21. Res. Quart. Am. Assoc. Health, Phys. Ed., Recr., *21:* 366–376.

United States Department of Commerce. Bureau of the Census 1952 1950 Population Census Report P-A52. Number of Inhabitants, Hawaii. U. S. Government Printing Office 1952, Reprint of vol. 1, chapter 52, 4 pp.

APPENDIX

TABLE 6

Heights and weights of daughters and mothers

Study no.	Height				Sitting height	Weight	
	Daughter		Mother		Daughter	Daughter	Mother
	cm	*in.*[1]	*cm*	*in.*[1]	*cm*	*lbs.*	*lbs.*
3	151.0	59.4	142.0	55.9	83.5	118.0	98
4	153.2	60.3	145.0	57.1	84.0	104.0	94
5	168.5	66.3	146.3	57.6	89.6	113.5	90
6	155.9	61.4	150.3	59.2	85.0	123.5	115
7	155.2	61.1	149.4	58.8	85.4	102.5	107
8	148.2	58.3	150.6	59.3	82.6	97.0	119
9	157.4	62.0	—	—	88.0	96.0	—
10	155.5	61.2	151.1	59.5	85.2	126.0	119
11	151.7	59.7	146.3	57.6	83.4	93.5	94
12	160.2	63.1	154.0	60.6	86.1	108.0	118
14	160.4	63.1	149.5	58.9	85.4	120.0	81
15	158.3	62.3	154.0	60.6	85.0	116.0	115
16	151.9	59.8	153.0	60.2	83.4	104.0	135
17	156.7	61.7	154.6	60.9	83.5	108.5	135
18	165.1	65.0	159.5	62.8	86.6	123.0	128
19	159.2	62.7	—	—	87.9	91.0	—
20	160.1	63.0	154.7	60.9	85.3	144.0	148
21	153.3	60.3	146.1	57.5	84.4	96.0	120
22	158.1	62.2	147.8	58.2	86.4	106.0	99
23	148.6	58.5	142.8	56.2	82.1	102.0	89
24	154.4	60.8	143.3	56.4	84.7	95.5	86
25	158.1	62.2	158.2	62.3	86.1	125.0	160
27	159.4	62.7	151.4	59.6	87.3	150.5	118
28	157.2	61.9	145.7	57.4	88.6	114.0	111
29	148.8	58.6	158.2	62.3	83.8	100.0	126
30	148.9	58.6	143.7	56.6	81.9	87.5	—
31	153.7	60.5	143.7	56.6	80.3	102.0	84
34	158.6	62.4	151.1	59.5	84.5	115.0	148
35	160.9	63.3	—	—	85.9	106.0	—
36	161.3	63.5	—	—	87.0	114.0	—
37	158.2	62.3	159.4	62.7	88.2	114.0	112
39	150.4	59.2	142.0	55.9	81.0	117.5	137
40	144.4	56.9	139.7	55.0	80.6	101.5	—
41	156.4	61.6	—	—	84.1	119.0	—
42	156.7	61.7	154.5	60.8	85.2	99.0	116
43	169.1	66.6	—	—	92.7	161.5	—
44	155.4	61.2	—	—	84.8	110.0	—
45	153.8	60.5	148.2	58.3	87.0	90.0	95
46	153.5	60.4	—	—	86.6	96.0	—
47	155.2	61.1	154.0	60.6	85.4	100.0	138
48	158.5	62.4	144.0	56.7	86.0	108.5	98
49	158.1	62.2	153.8	60.5	83.2	99.0	142
51	151.4	59.6	159.0	62.6	80.2	131.5	122
52	162.5	64.0	154.5	60.8	90.5	115.0	116
53	154.9	61.0	151.5	59.6	85.0	131.0	158
54	154.5	60.8	—	—	84.2	113.5	—
56	157.9	62.2	151.3	59.6	86.4	112.0	183
57	162.1	63.8	144.0	56.7	84.8	117.0	104
58	162.7	64.0	147.2	58.0	88.5	109.0	140
59	153.7	60.5	—	—	82.0	93.0	—
61	154.6	60.9	147.0	57.9	83.6	119.0	100
62	153.9	60.6	155.7	61.3	84.9	107.0	123
63	153.3	60.3	147.6	58.1	87.6	93.0	116
64	153.8	60.5	152.0	59.8	83.1	95.0	140
65	156.9	61.8	151.8	59.8	83.8	111.5	130
66	156.5	61.6	148.8	58.6	85.0	114.0	121
67	155.4	61.2	—	—	84.2	124.0	—
68	151.2	59.5	142.3	56.0	84.2	113.0	100
69	158.4	62.4	142.9	56.3	87.3	142.0	114

TABLE 6 (*Continued*)

Heights and weights of daughters and mothers

Study no.	Height				Sitting height	Weight	
	Daughter		Mother		Daughter	Daughter	Mother
	cm	*in.*[1]	*cm*	*in.*[1]	*cm*	*lbs.*	*lbs.*
70	156.4	61.6	160.7	63.3	85.0	123.0	123
71	154.0	60.6	159.3	62.7	81.8	111.5	140
72	151.1	59.5	150.9	59.4	83.2	93.0	114
73	143.0	56.3	141.6	55.7	77.5	82.5	119
75	154.3	60.7	150.4	59.2	85.1	100.0	91
76	152.8	60.1	147.0	57.9	85.3	83.5	106
78	159.4	62.7	152.8	60.1	87.6	123.0	105
80	146.0	57.5	152.2	59.9	79.2	94.0	110
82	155.2	61.1	154.4	60.8	84.6	105.5	116
83	153.4	60.4	—	—	82.4	134.0	—
84	152.8	60.1	147.7	58.1	81.7	119.0	124
85	155.6	61.3	139.3	54.8	85.3	120.0	88
86	153.3	60.3	146.3	57.6	82.8	98.0	97
87	156.2	61.5	—	—	86.0	117.0	—
88	148.7	58.5	147.5	58.1	82.4	96.0	115
89	151.3	59.6	—	—	81.7	97.0	—
90	151.9	59.8	145.7	57.4	82.5	97.5	138
91	155.4	61.2	147.5	58.1	85.2	97.0	123
92	157.3	61.9	—	—	84.4	142.0	—
94	157.4	62.0	—	—	87.3	104.0	—
95	153.1	60.3	148.3	58.4	83.6	91.0	118
96	155.6	61.3	156.0	61.4	83.9	100.5	125
97	158.1	62.2	153.6	60.5	83.3	97.0	109
99	161.9	63.7	—	—	89.0	142.0	—
100	154.5	60.8	—	—	83.1	105.0	—
101	154.1	60.7	147.6	58.1	83.2	117.0	95
102	157.2	61.9	143.7	56.6	83.2	111.0	105
103	154.5	60.8	151.0	59.4	86.3	109.0	—
104	160.5	63.2	146.0	57.5	86.0	106.0	102
106	158.0	62.2	148.6	58.5	83.9	123.5	—
107	158.3	62.3	148.1	58.3	85.8	107.0	107
108	156.2	61.5	150.8	59.4	86.7	133.0	128
109	159.3	62.7	155.2	61.1	85.2	132.0	133
110	161.9	63.7	145.2	57.2	86.6	121.0	104
111	158.4	62.4	—	—	86.1	104.0	—
112	149.7	58.9	—	—	80.8	96.0	—
113	163.0	64.2	157.8	62.1	86.2	108.0	102
114	155.5	61.2	144.0	56.7	83.8	103.0	108
115	154.0	60.6	153.5	60.4	83.5	92.0	147
116	157.1	61.8	—	—	85.1	104.0	—
117	158.0	62.2	152.4	60.0	85.7	110.0	123
118	156.0	61.4	151.7	59.7	86.9	107.5	110
119	153.4	60.4	147.9	58.2	85.0	108.0	—
120	150.0	59.1	142.8	56.2	84.1	94.0	102
121	152.5	60.0	155.0	61.0	81.9	110.5	137

	Height		Weight	
	Daughter	Mother	Daughter	Mother
	cm	*cm*	*lbs.*	*lbs.*
Total no.	104	83	104	78
Mean	155.7	149.7	109.9	116.7
S. D.	4.4	5.1	14.7	19.3
S. E.	0.4	0.6	1.4	2.2
83 daughters whose mothers were measured			78 daughters whose mothers were weighed	
Mean	155.4		109.3	
S. D.	4.4		13.6	
S. E.	0.5		1.5	

---

[1] Conversion table 33—centimeters to inches. Rose's Laboratory Handbook for Dietetics. C. M. Taylor and G. Macleod. MacMillan, New York, 1949.

TABLE 7

Heights and weights of sons and fathers

Study no.	Height				Sitting height	Weight	
	Son		Father		Son	Son	Father
	cm	*in.*[1]	*cm*	*in.*[1]	*cm*	*lbs.*	*lbs.*
130	168.6	66.4	160.0	63.0	92.3	126.5	133
131	173.0	68.1	162.5	64.0	94.5	103.5	110
132	164.0	64.6	154.0	60.6	88.0	120.0	88
133	161.4	63.5	—	—	92.0	145.0	—
134	170.7	67.2	166.2	65.4	94.0	121.0	128
135	168.6	66.4	161.2	63.5	90.5	127.0	110
136	163.3	64.3	161.3	63.5	89.3	120.0	—
137	160.4	63.1	155.7	61.3	86.6	112.5	108
138	164.3	64.7	—	—	89.3	140.0	—
139	166.0	65.3	158.5	62.4	90.6	122.0	120
141	163.8	64.5	161.2	63.5	87.6	105.5	128
142	179.2	70.6	170.2	67.0	97.5	197.0	—
143	170.4	67.1	165.9	65.3	93.0	112.0	—
144	163.2	64.2	159.4	62.7	88.0	109.0	—
145	165.0	64.9	—	—	92.6	137.5	—
146	167.3	65.9	159.0	62.6	92.0	138.0	124
147	166.4	65.5	162.2	63.8	90.4	126.5	151
148	163.5	64.4	—	—	89.2	119.0	—
149	166.5	65.5	158.8	62.5	89.0	137.0	130
150	168.4	66.3	168.9	66.5	89.8	125.0	168
151	172.7	68.0	160.4	63.1	91.7	136.0	140
152	152.4	60.0	150.4	59.2	86.1	123.0	—
153	161.4	63.5	143.2	56.4	88.0	128.0	93
154	174.4	68.7	162.3	63.9	92.5	133.5	140
155	164.0	64.6	161.0	63.4	89.2	124.5	—
156	168.7	66.4	164.6	64.8	90.8	140.5	—
157	157.5	62.0	154.2	60.7	86.4	140.0	—
158	165.2	65.0	169.5	66.7	91.4	130.5	—
159	175.0	68.9	164.0	64.6	96.1	128.0	—
160	169.0	66.5	—	—	94.7	138.5	—
161	171.0	67.3	167.5	65.9	95.0	139.0	—
162	166.6	65.6	156.3	61.5	91.0	140.5	96
163	167.6	66.0	164.8	64.9	88.8	135.0	134
164	168.8	66.4	—	—	90.8	120.0	—
165	168.4	66.3	160.7	63.3	88.4	123.5	—
166	163.4	64.3	160.0	63.0	89.2	132.5	—
167	165.5	65.1	—	—	89.2	163.5	—
168	174.6	68.7	160.0	63.0	94.2	146.5	—
169	179.0	70.5	167.8	66.1	94.4	170.0	—
170	157.7	62.1	157.5	62.0	86.8	116.0	143
171	182.1	71.7	163.9	64.5	94.0	169.0	—
172	169.6	66.8	—	—	89.1	113.5	—
173	166.4	65.5	—	—	92.6	131.0	—
174	167.5	65.9	158.0	62.2	90.2	135.5	143
175	166.4	65.5	—	—	90.1	130.0	—
176	156.7	61.7	—	—	84.5	100.5	—
177	160.7	63.3	156.7	61.7	90.0	145.0	—
178	167.1	65.8	166.4	65.5	94.6	176.0	140
179	163.9	64.5	155.6	61.3	89.9	140.0	—
180	165.5	65.1	154.8	60.9	90.1	125.0	120
181	174.7	68.8	—	—	92.6	150.0	—
182	168.6	66.4	—	—	91.7	127.0	—
183	168.0	66.1	—	—	90.8	130.0	—
184	168.4	66.3	158.0	62.2	90.8	132.0	138
185	168.5	66.3	151.0	59.4	91.8	137.5	110
186	166.1	65.4	165.0	64.9	91.8	111.5	136
187	163.5	64.4	160.0	63.0	88.8	123.0	143
188	179.5	70.7	171.0	67.3	96.5	162.5	—
189	171.6	67.5	156.2	61.5	96.2	136.5	127
190	161.2	63.5	—	—	88.1	111.5	—

TABLE 7 (*Continued*)

Heights and weights of sons and fathers

Study no.	Height				Sitting height	Weight	
	Son		Father		Son	Son	Father
	cm	*in.*[1]	*cm*	*in.*[1]	*cm*	*lbs.*	*lbs.*
191	158.3	62.3	149.0	58.7	87.3	124.5	121
192	167.2	65.8	—	—	93.5	103.0	—
193	171.5	67.5	162.5	64.0	90.8	121.0	—
194	158.7	62.5	162.0	63.8	88.7	116.5	136
195	185.5	73.0	173.0	68.1	99.5	149.0	—
196	153.4	60.4	—	—	84.0	103.5	—
197	161.6	63.6	—	—	87.6	112.0	—
198	164.4	64.7	—	—	89.6	140.0	—
199	170.4	67.1	154.9	61.0	92.5	145.0	130
200	159.1	62.6	—	—	88.1	127.5	—
201	175.4	69.1	160.2	63.1	96.0	142.0	88
202	170.8	67.2	173.8	68.4	93.0	124.0	148
203	167.5	65.9	—	—	90.0	116.0	—
204	165.0	64.9	156.0	61.4	92.0	139.0	—
205	167.3	65.9	159.0	62.6	91.3	132.0	98
206	165.8	65.3	163.4	64.3	91.2	129.5	—
207	164.4	64.7	—	—	90.9	126.0	—
208	164.2	64.6	160.0	63.0	89.4	115.5	—
209	156.9	61.8	154.5	60.8	86.7	135.5	124
210	167.4	65.9	159.2	62.7	91.8	118.0	—
211	170.2	67.0	155.8	61.3	91.8	130.5	—
212	157.9	62.2	—	—	87.9	111.5	—
213	168.8	66.4	165.2	65.0	88.3	144.5	—
214	162.2	63.8	167.4	65.9	88.3	133.0	—
215	167.3	65.9	141.6	55.7	89.0	123.0	89
216	158.9	62.5	151.2	59.5	86.0	120.0	89
217	171.4	67.5	152.2	59.9	93.2	135.5	148
218	170.8	67.2	162.1	63.8	91.1	139.0	146
219	165.0	64.9	158.2	62.3	92.5	134.5	122
220	163.0	64.2	165.4	65.1	89.2	129.0	113
221	176.0	69.3	170.8	67.2	94.6	147.5	111
222	162.1	63.8	159.8	62.9	87.7	121.5	—
223	172.7	68.0	166.3	65.5	92.6	130.0	—
224	159.0	62.6	159.5	62.8	87.1	114.5	—
225	169.1	66.6	157.8	62.1	91.0	147.5	128
226	166.9	65.7	166.6	65.6	90.2	143.0	—
227	172.3	67.8	169.4	66.7	90.0	120.0	—
228	170.2	67.0	152.0	59.8	93.5	168.0	118
229	167.6	66.0	167.1	65.8	91.0	124.0	—
230	175.1	68.9	156.5	61.6	90.1	128.0	—
231	165.5	65.1	148.5	58.5	87.5	118.5	—
232	163.0	64.2	165.6	65.2	90.2	127.0	—
233	154.1	60.7	156.1	61.4	86.1	119.0	—
234	168.7	66.4	—	—	92.1	138.5	—

	Height		Weight	
	Son	Father	Son	Father
	cm	*cm*	*lbs.*	*lbs.*
Total no.	104	80	104	42
Mean	166.8	160.4	130.8	124.0
S. D.	5.9	6.3	16.1	19.5
S. E.	0.6	0.7	1.6	3.0

	80 sons whose fathers were measured	42 sons whose fathers were weighed
Mean	167.4	130.8
S. D.	6.1	14.0
S. E.	0.7	2.2

---

[1] Conversion table 33—centimeters to inches. Rose's Laboratory Handbook for Dietetics. C. M. Taylor and G. Macleod. MacMillan, New York, 1949.

Physiques of Hawaii-Born Young Men and Women of Japanese Ancestry, Compared with College Men and Women of the United States and England[1]

BARBARA HONEYMAN HEATH,[2] CARL E. HOPKINS[3] AND CAREY D. MILLER[4]
Foods and Nutrition Department, University of Hawaii Agricultural Experiment Station, Honolulu, Hawaii

To the extent that the somatic characteristics described by somatotyping (Tanner, '52) of physique represent distinct combinations of genetic factors, differences in somatotype distributions of various populations might serve as do blood group distributions, to differentiate races or ethnic subdivisions of mankind carrying numerous genes in common. While there is some literature describing the somatotype distribution of American[5] and English university men (Tanner, '52), there is a dearth of comparative studies of different ethnic groups. The present report contributes such material.

Studies of stature in Hawaii by Miller ('61) have afforded material for somatotyping of a series of Hawaii-born youth of Japanese ancestry. In 1949 Miller made uniform somatotype photographs of 104 male and 104 female students of the University of Hawaii whose parents were Japanese. She also obtained height and weight data on some of the parents.

MATERIAL AND METHODS

The subjects were recruited from the student body through the physical education classes. They were 18 to 22 years old.

As part of a general dental and nutrition study, the subjects were weighed, without clothing, in pounds. Stature was measured in centimeters and converted to inches. Somatotype photographs, front, side, and back, were taken with a view camera on 5″ × 7″ film at 7 feet from the lens, giving a picture 30% larger than the standard photo suggested by Sheldon. Primary and secondary sexual landmarks, including the face, were covered in the manner illustrated in figures 1 and 2, in order to gain cooperation of the subjects. These departures from standard technique had some nuisance value in the somatotype rating, but are considered to have had little effect on accuracy of the ratings. Detailed notes on the technique of anthroposcopic somatotype rating will be presented in another paper, but the essential steps are:

1. Compute ponderal index—height divided by cube root of weight—by use of a nomogram.
2. Enter height/weight$^{1/3}$ into the Sheldon reference table (amended by BHH). This table gives the several somatotype ratings admissible for that height/weight$^{1/3}$ ratio.
3. The best of the few admissible ratings is selected by eye. This step is not difficult. The dominant component, if any, is estimated by inspection, and this is usually sufficient to distinguish among the few possibilities presented by the height/weight$^{1/3}$ index, as, for instance, 252 and 522.

The subjects were Hawaii-born with both parents of Japanese ancestry born in Asia or in Hawaii. The sample obtained in this fashion is 55% first generation island-born children, about 20% second island-born generation, and the remainder one parent born in Asia and the other in Hawaii.

---

[1] Published with the approval of the Director of the Hawaii Agricultural Experiment Station as Technical Paper no. 462.

[2] 5 Via Joaquin, Monterey, California.

[3] University of Oregon Medical School, Portland 1, Oregon.

[4] University of Hawaii, Honolulu 14, Hawaii.

[5] In this paper, "American" refers to residents of the United States of America predominantly of Caucasian ancestry unless otherwise specified.

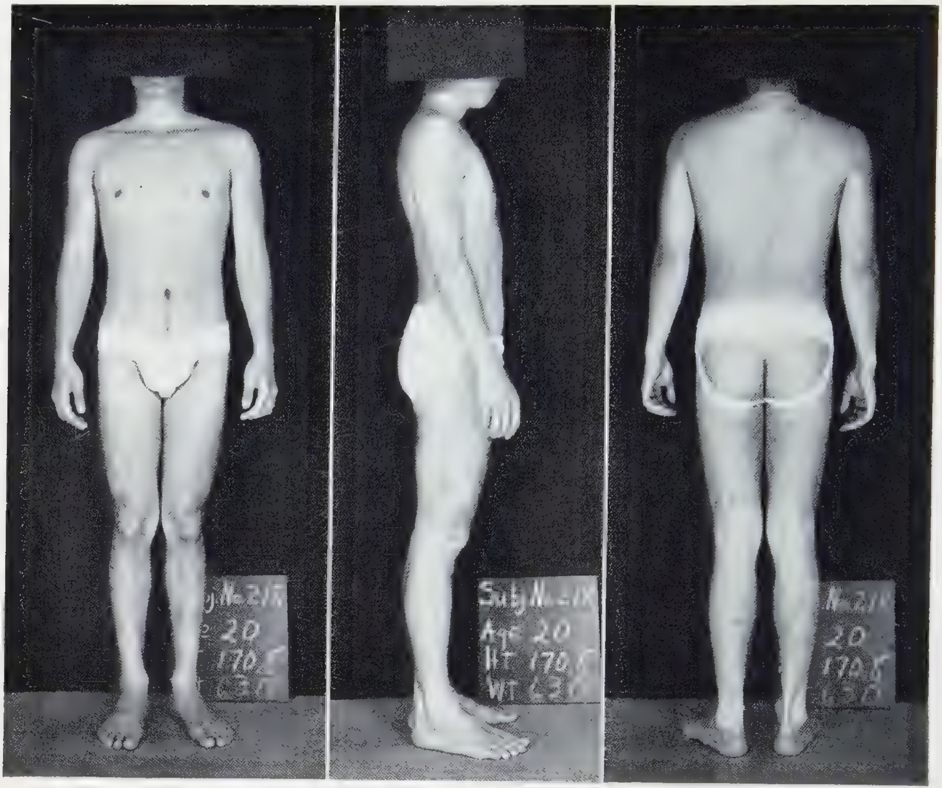


Fig. 1 Typical photographs used for somatotype rating of male subjects.

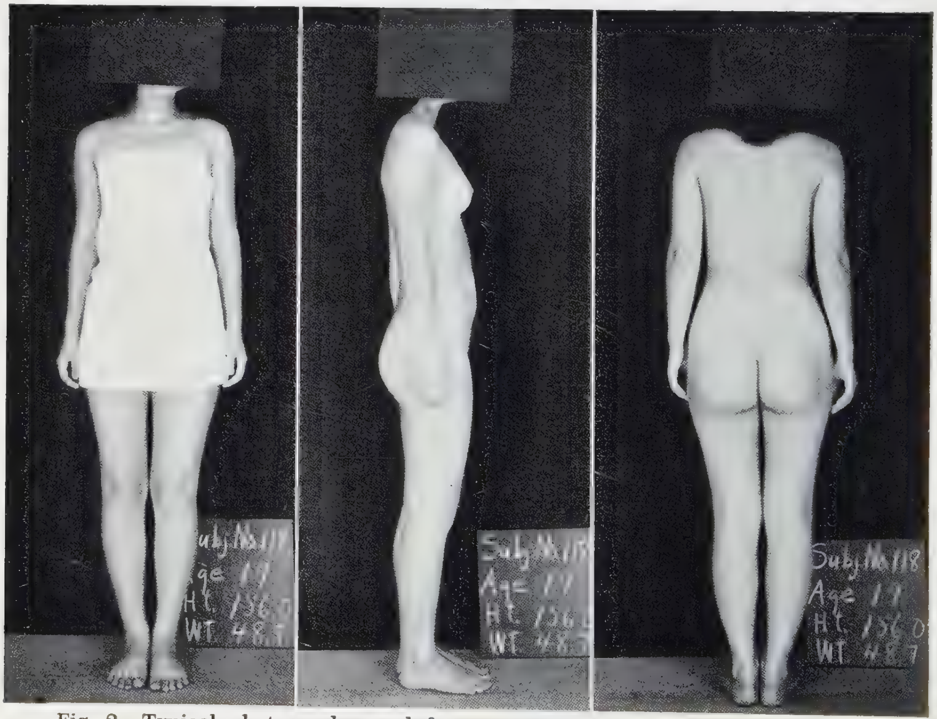


Fig. 2 Typical photographs used for somatotype rating of female subjects.

The university sample is 208 volunteers rom among some 1000 potentially eligible tudents at the University. (Exact ethnic ensus of the university population is not vailable.) Although voluntary, the samle appears to represent the young men nd women of Japanese ancestry of the Jniversity and also of the Hawaiian Isands in general. The distribution of parnts' occupations and of ethnic names in he university registry of students is simlar to that of the sample. The geographic distribution of residence in the sample is roughly similar to that for the total population of the Islands.

RESULTS AND DISCUSSION

1. The distribution of somatotypes in this series shows a heavy concentration in the second component-dominant category, as compared with Sheldon's U. S.[6] males

TABLE 1

Somatotype distribution of University of Hawaii Japanese ancestry men compared with Sheldon's U. S. Men (per cent)

	University of Hawaii	U. S. Men	Difference sig. at 5% level
	%	%	
First component dominant[1]	*1*	*13*	*
543	1	2	
Other	—	11	*
Second component dominant	*74*	*34*	*
163	2	—	
253	3	4	
254	10	3	*
262	3	1	
263	9	1	*
271	1	1	
352	2	3	
353	15	6	*
354	8	4	
362	7	2	
371	1	—	
372	1	—	
452	2	5	
453	4	3	
461	2	—	
462	2	1	
561	2	—	
Other	—	—	
Third component dominant	*16*	*21*	
145	1	—	
236	4	2	
245	7	2	
345	4	3	
Other	—	14	*
Balanced	*9*	*32*	*
344	3	6	
444	3	4	
551	1	—	
552	2	—	
Other	—	22	*
All	100	100	

[1] Means and variances of separate components of these distributions will not necessarily equal the statistics given in table 2. Table 2 is computed from somatotype ratings made to the nearest *half-step* and these are to be regarded as definitive ratings. When such ratings are "rounded," as for table 1, the rounding is not mathematically straightforward, but includes some judgment elements. For instance, the somatotype 4½ 3½ 3 does not necessarily round, as it would by mathematical convention, to 443, but may by the anthroposcopist be rounded instead to 543 as representing the presenting physique better than 443.

---

[6] U. S. is used throughout to indicate United States of America.

(Sheldon, '54). Table 1 gives the percentage distribution according to the more frequently found somatotypes, using the standard numerical notation in which the first digit is the rating on a seven-point scale of the *first component* (fatness, "endomorphy"); the second digit rates the *second component* (muscularity, "mesomorphy"), and the third digit rates the *third component* (linearity, "ectomorphy").

It is evident here that the "fat" and "balanced" somatotypes are much rarer and the "muscular" somatotypes much more frequent in the Japanese[7] men than in the American men.

2. Statistics of height, weight, ponderal index, and somatotype components are shown in table 2, compared with two American series from the literature and with 4 English series of young men phot graphed by Tanner and rated by one us (BHH).

The distributions of these measures a reasonably symmetrical, as can be see in figure 3, where the separate somat type components of the Hawaii Japanes men are compared with Sheldon's U. men.

3. Plotting on Normal probability pape (fig. 4) showed these distributions to b well fitted by the Normal distribution be tween the 5th and 95th centiles, and sub sequent analysis will treat the data as i

---

[7] The term Japanese is used throughout thi paper to indicate the University students of Ja anese ancestry, who by right of birth are als American.

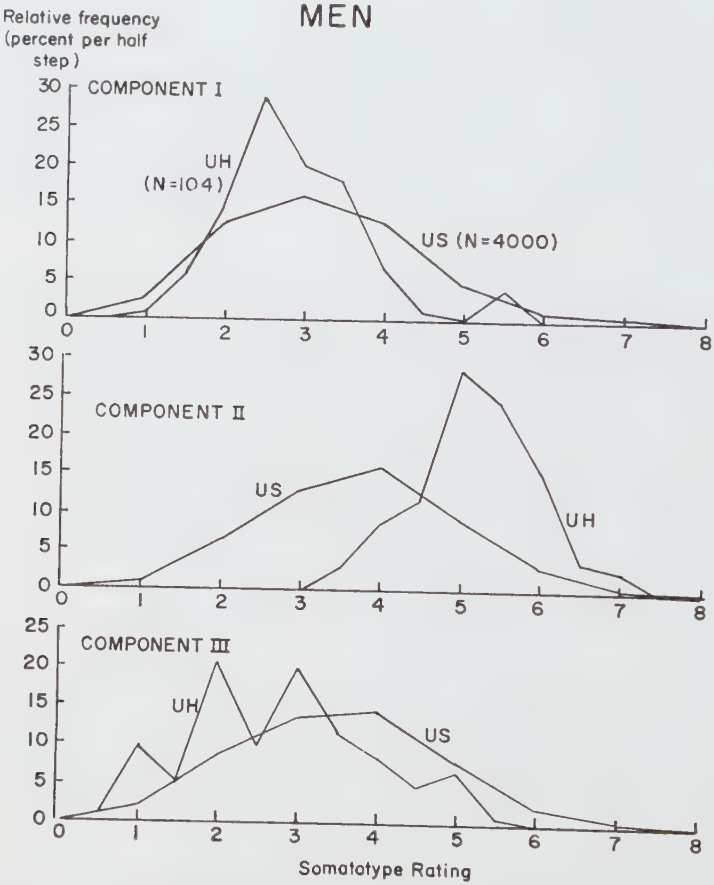


Fig. 3 Frequency distributions of single somatotype component ratings, University of Hawaii Japanese men, and 4000 U. S. college men, from Sheldon ('40, p. 127).

they were adequately summarized by their means and standard deviations.

4. Table 3 exhibits comparisons of the Hawaii series with each of the other series. From table 3 it can be seen that the Hawaii Japanese men as compared with U. S. series are about 3 inches shorter, 10 lb. lighter, have a slightly lower ponderal index, are nearly half a unit lower in the first somatotype component, about 4/3 units higher in the second component, and 6/10 units lower in the third. As compared with the English series the same differences appear and to a greater degree. In physical terms the Japanese men are shorter, stockier, more muscular than the American and English college men. These differences are all significant at the 5% probability level by individual t tests.

Table 4 shows the Japanese men to be somewhat more homogeneous (smaller standard deviation) than the U. S. college men. In the first and second components the Hawaii Japanese show definitely less variation, and in the third component the difference is apparent but not quite significant at the 5% level. Because, however, of differences in scale of the two groups, comparison of their *relative* variation has more direct meaning. Here it is seen that the two series do not differ much in *relative* variation except in the second component, where the very high mean rating of the Japanese men gives them a very small coefficient of variation. It is evident from the standard deviations of heights and weights that the Japanese

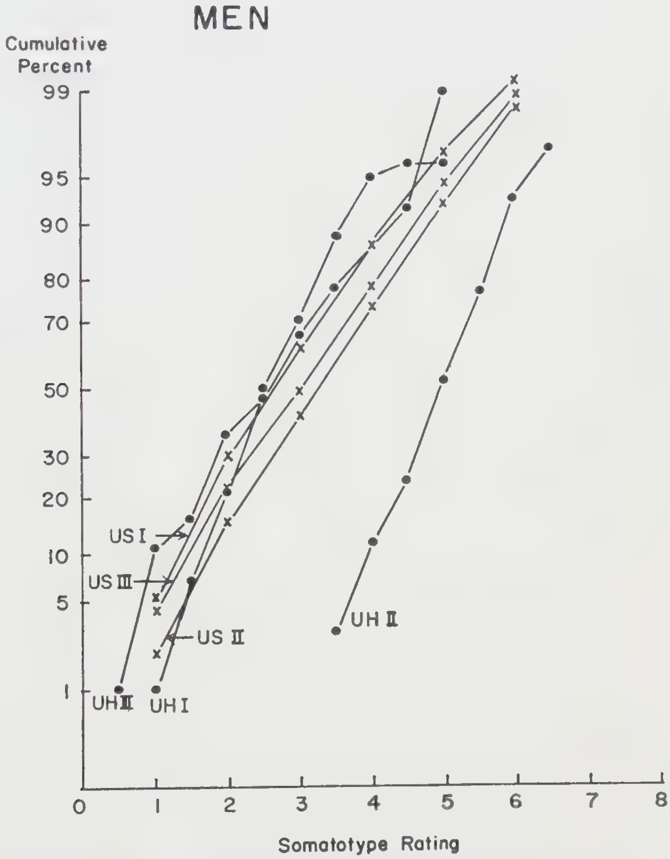


Fig. 4 Normal probability plot of cumulative frequency distributions of separate somatotype component ratings (I, II, III) for University of Hawaii Japanese men (UH) and U. S. college men (US).

TABLE 2

Body measurements of University of Hawaii Japanese men compared with other series (means and standard deviations)

Series	N	Height	Weight	Ht./Wt.$^{1/3}$	First component (fatness)	Second component (muscle)	Third component (linearity)
		in.	*lb.*				
Hawaii Japanese	104	65.7 +2.40	130 +16	12.97+0.53	2.87+0.88	5.21+0.76	2.83+1.16
Atlas of Men[1]	46000	68.53 +NA	140 +NA	13.10+NA	3.34+1.10	4.11+1.03	3.42+1.16
U. S. College Men[2]	4000	68.82*+NA	142*+NA	13.19+NA[3]	3.20+1.2	3.77+1.2	3.53+1.3
English Series I	286	70.98 +2.43	152 +14	13.32+0.38	2.98+0.55	4.34+0.85	3.73+0.96
English Series IIB	42	70.75 +2.35	159 +15	13.13+0.50	2.90+0.76	4.24+0.93	3.74+0.98
English Series IIC	65	70.50 +2.70	155 +17	13.16+0.91	3.25+0.91	4.24+0.91	3.55+1.18
English Series IID	40	70.67 +2.39	154 +17	13.22+0.52	3.00+0.95	4.18+0.97	3.80+1.33

[1] Sheldon, '54, p. 30 ff.

[2] Sheldon et al., '40, p. 127.

[3] Sheldon, '54, p. 13.

* Calculated from table 23A in reference (Sheldon et al., '40, p. 268).

NA, standard deviation not available.

TABLE 3

Body measurements of University of Hawaii Japanese men compared with other series (Japanese series mean minus other series mean + standard error of difference)

Other series	Height	Weight	Ht./Wt.$^{1/3}$	First component	Second component	Third component
	in.	*lb.*				
Atlas of Men	−2.88 +NA	− 9.00 +NA	−0.15 +NA	−0.47*+0.09	+1.10*+0.07	−0.59*+0.11
U. S. College Men	−3.17 +NA	−11.20 +NA	−0.24 +NA	−0.33*+0.09	+1.44*+0.08	−0.70*+0.12
English Series I	−5.33*+0.28	−21.00*+1.77	−0.37*+0.06	−0.11 +0.09	+0.87*+0.09	−0.90*+0.13
English Series IIB	−5.10*+0.43	−28.00*+2.80	−0.18*+0.09	−0.03 +0.15	+0.97*+0.16	−0.91*+0.19
English Series IIC	−4.85*+0.41	−24.00*+2.63	−0.21 +0.12	−0.38*+0.19	+0.97*+0.14	−0.72*+0.18
English Series IID	−5.02*+0.46	−23.00*+3.12	−0.27*+0.94	−0.13 +0.17	+1.03*+0.17	−0.97*+0.24

* Significant at 5% level, individual t-tests.

NA, standard deviation not available.

TABLE 4

Variance ratios and coefficients of variation of University of Hawaii Japanese men compared with U. S. college men

	Variance ratio		Coefficient of variation (standard deviation/mean)	
	U.S./U.H.	P	U.S.	U.H.
First component	1.86[1]	< 0.02	0.38	0.31
Second component	2.50[1]	< 0.02	0.32	0.15
Third component	1.26	> 0.10	0.37	0.41

[1] Significant at 5% level.

have the same degree of homogeneity as the other series.

Comparison with the English series shows the same general differences, except for considerably less difference in variation. This is to be expected because the English series, particularly Series I, are from schools that select young men capable of vigorous physical performance.

METHODOLOGICAL NOTES

1. The usual practice of analysis and interpretation of the three somatotype component ratings separately as if they were three independent variates introduces a degree of artificiality into somatotype analysis. Since these three ratings usually add only to 10, 11, 12 or possibly 13, it is obvious that they are not independent. And indeed, their intercorrelations have been studied (Sheldon et al., '40) and found to be high. For this reason an analysis in the form of a tri-variate normal frequency distribution would seem to be more appropriate as well as more arduous. Table 1, giving the frequency distribution of the principal rating combinations as they are found, is a practical substitute for this kind of analysis, giving the relative frequencies for a few selected volumes of the three-dimensional distribution.

2. Analysis of variance of the height, weight, ponderal index and somatotype ratings in the several series would ordinarily seem to be appropriate, but in this instance, where we are comparing different ethnic groups having considerable differences in both scale (variances) and sample size, the assumptions underlying

TABLE 5

Variance ratios: Analysis of variance

Trait	Between origins F	Series within origin F	M. S. subjects within series
	Men		
	(1 d.f.)	(3 d.f.)	(532 d.f.)
Height (inches)	469.86[1]	0.81	5.94
Weight (pounds)	61.84[1]	3.00[2]	228.49
Height/weight$^{1/3}$	10.26[2]	4.25[2]	0.19
Component I	0.64	5.27[2]	0.54
Component II	10.25[2]	11.92[2]	0.72
Component III	7.33[2]	7.73[2]	2.05
	Women		
	(2 d.f.)	(7 d.f.)	(2834 d.f.)
Height (inches)	14.26[2]	9.24[2]	5.34
Weight (pounds)	11.90[2]	5.26[2]	246.08
Height/weight$^{1/3}$	0.57	6.87[2]	0.25
Component I	0.64	9.04[2]	0.67
Component II	10.04[2]	15.58[2]	0.57
Component III	2.03	6.42[2]	1.30

[1] Significant at 0.01 level.

[2] Significant at 0.05 level.

the analysis of variance do not hold strictly and the analysis may produce strange results, particularly when it comes to examination of the individual contrasts. For instance, the standard error of any mean of the U. S. college men (N–4000) or of Sheldon's 46,000 U. S. men would be very small, so that if a pooled error term is used almost any other series would show a significant difference from either of these large series.

Partly to alleviate this difficulty, the mammoth U. S. series were excluded from the hierarchal analysis of variance. The resultant variance ratios show significant differences among origins for all the traits except Component I in the men. In the women the origin means are different on height, weight and Component II. As among series from the same origin, all traits show inter-series differences in both sexes, with the single exception of height in men. (See table 5.)

The error variances (M.S. subjects within series) obtained from the analysis of variance could be used to investigate the single contrasts among the series means using Snedecor's Q test (Snedecor, '57) or Duncan's Multiple Range test (Duncan '55). Most of these contrasts, even when the two very large U.S. series are excluded will turn out to be significant, because of the large sample sizes. Statistical significance, while necessary to interpretation of differences between series, is not sufficient to indicate importance of the phys-

TABLE 6

Somatotype distribution of University of Hawaii Japanese women, compared with U. S. college women (per cent)

Somatotype	Hawaii Japanese	U. S. College	Difference significant at 5% level
	%	%	
First component dominant[1]	*38.9*	*35.0*	
651	1.0	0.4	
641	1.0	0.6	
642	2.9	1.9	
542	12.6	7.3	
543	7.8	6.3	
532	2.0	4.2	
533	3.9	8.1	
534	5.8	4.3	
523	1.0	1.9	
Second component dominant	*4.9*	*1.3*	
452	4.9	1.3	
Third component dominant	*8.9*	*10.4*	
226	1.0	0.5	
336	1.0	0.2	
335	1.0	1.9	
435	4.9	5.2	
425	1.0	2.6	
Balanced	*47.6*	*30.7*	*
334	1.9	2.1	
344	1.0	1.1	
343	1.9	0.8	
424	1.0	2.4	
433	3.9	5.4	
434	10.7	6.0	
443	8.7	4.1	
444	5.8	4.2	
442	3.9	2.5	
551	1.0	0.7	
552	7.8	1.4	*
Miscellaneous others	—	22.8	*
All	100.3	100.2	

[1] See footnote to table 1.

al magnitudes involved. Since final interretation must rest on the physical nplications of the magnitudes, these nagnitudes with their standard errors are xhibited in table 3 (men) and table 8 women) for the Hawaiian Japanese seies compared singly with each of the ther series.

The Women

1. In distribution of somatotype freuencies (table 6) the Japanese women re not as different from their U. S. college ounterparts as were the men. Both ethnic lasses have a similarly high relative freuency of first component dominance, ecause they are women. The only sigificant differences are in the "balanced" and the "miscellaneous others" categories. The Japanese women have a 50% higher frequency of balanced types. This may be interpreted as being the result of their increased second component (muscularity) which, combined with the usual female "fatness" (first component), places them in the balanced component category.

2. Statistics of height, weight, ponderal index, and somatotype components are shown in table 7 for the women, along with several series of American and English college women from Heath (unpublished data).

3. These distributions, like those for the men, are reasonably symmetrical (fig. 3) and the distributions of the somatotype components are essentially Normal (fig. 4).

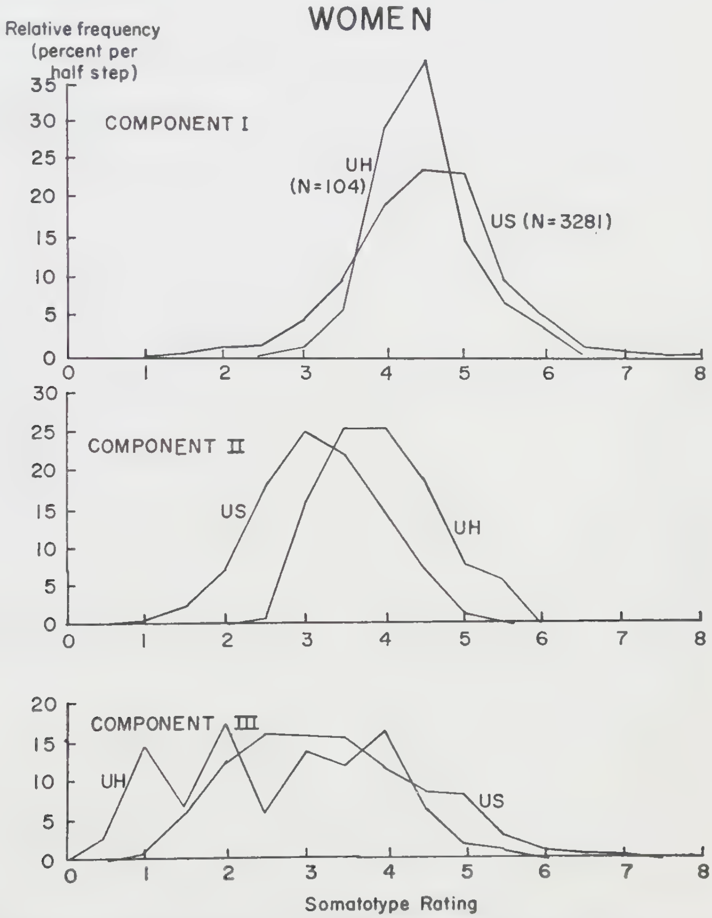


Fig. 5 Frequency distributions of single somatotype component ratings, University of Hawaii Japanese women, and 3281 U. S. college women, from Heath.

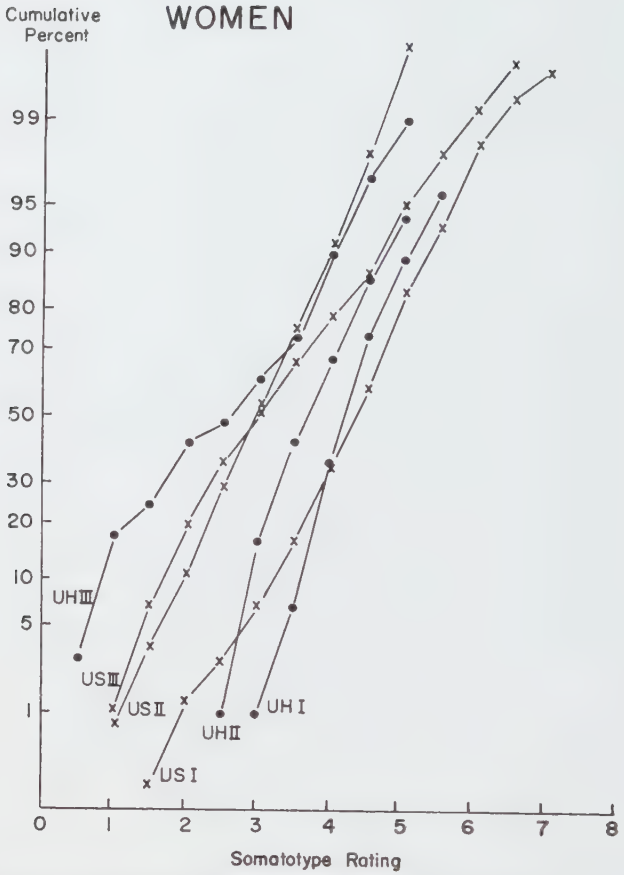


Fig. 6 Normal probability plot of cumulative frequency distributions of separate somatotype component ratings (I, II, III) for University of Hawaii Japanese women (UH) and U. S. college women (US).

4. Referring to table 8 it can be seen that the Hawaii Japanese women as compared with American and English college women are nearly 4″ shorter, 15 to 20 lb. lighter, have a slightly lower ponderal index, are similar in the first component, considerably more muscular (second component), and somewhat less linear (third component). In physical terms, they are generally smaller people, somewhat more muscular, but otherwise rather similar in physique to the American and English women.

5. The Hawaii Japanese women are somewhat more homogeneous (smaller standard deviation) than the U. S. college women. Comparing (table 9) the Hawaii series with the 6 U. S. series pooled, we see that the U. S. women are significantly more variable in height, fatness (first component), and muscularity (second component). Relative variation, however, as expressed by the coefficient of variation, turns out to be nearly identical for the two ethnic samples, except on the first component, for which the large standard deviation of the U. S. women is associated with a low mean.

SUMMARY

A series of 104 young men and 104 young women university students born in Hawaii of Japanese parents were somatotyped and compared with mainland American and English series of college men and women.

The Hawaii-born Japanese men are shorter and lighter than the American and

TABLE 7

Body measurements of University of Hawaii Japanese women compared with other series (means and standard deviations)

Series	N	Height	Weight	Ht./Wt.$^{1/3}$	First component (fatness)	Second component (muscle)	Third component (linearity)
		in.	*lb.*				
Hawaii Japanese	102	61.28+1.72	110+15	12.84+0.47	4.48+0.59	3.96+0.71	2.72+1.24
U. S. Series I	192	64.77+2.20	126+14	12.93+0.50	4.20+0.90	3.25+0.75	3.40+1.10
U. S. Series II	658	64.68+2.44	127+17	12.89+0.56	4.68+0.88	3.08+0.75	3.20+1.18
U. S. Series III	375	65.07+NA	127+NA	12.93+NA	4.47+0.82	3.31+0.78	3.22+1.15
U.S. Series IV	216	65.22+2.57	125+16	13.08+0.50	4.49+0.83	2.99+0.73	3.50+1.14
U. S. Series V	413	64.75+2.23	126+17	12.95+0.55	4.50+0.91	3.24+0.77	3.38+1.26
U. S. Series VI	580	65.58+2.33	129+15	12.94+0.44	4.46+0.80	3.32+0.79	3.17+1.05
Total U. S. Series	2434	65.02+2.36	127+16	12.94+0.52	4.51+0.86	3.21+0.89	3.27+1.15
English Series I	112	64.70+2.12	132+13	12.72+0.35	4.49+0.49	4.31+0.62	2.73+0.85
English Series II	57	65.59+2.01	133+11	12.87+0.45	4.24+0.66	3.78+0.75	3.36+1.29
English Series III	136	64.7 +NA	124+NA	13.01+NA	4.26+NA	3.63+NA	3.36+NA

NA, standard deviation not available.

TABLE 8

Body measurements of University of Hawaii Japanese women compared with other series (Japanese series mean minus other series mean + standard error of difference)

Other series	Height	Weight	Ht./Wt.$^{1/3}$	First component	Second component	Third component
	in.	*lb.*				
U. S. Series I	−3.48*+0.23	−16.12*+1.73	−0.09 +0.06	+0.28*+0.09	+0.71*+0.09	−0.68*+0.15
U. S. Series II	−3.40*+0.19	−17.10*+1.58	−0.05 +0.05	−0.20*+0.07	+0.88*+0.08	−0.48*+0.13
U. S. Series III	−3.79 +NA	−17.10 +NA	−0.09 +NA	+0.01 +0.07	+0.65*+0.08	−0.50*+0.14
U. S. Series IV	−3.94*+0.24	−15.10*+1.79	−0.24*+0.06	−0.01 +0.08	+0.97*+0.09	−0.78*+0.15
U. S. Series V	−3.47*+0.20	−16.10*+1.65	−0.11*+0.05	−0.02 +0.07	+0.72*+0.03	−0.66*+0.14
U. S. Series VI	−4.30*+0.19	−19.10*+1.56	−0.10*+0.05	+0.02 +0.07	+0.64*+0.07	−0.45*+0.13
Total U. S. Series	−3.74*+0.17	−17.15*+1.47	−0.10*+0.05	−0.03 +0.06	+0.75*+0.07	−0.55*+0.13
English Series I	−3.42*+0.26	−22.10*+1.91	−0.12*+0.06	−0.01 +0.07	−0.35*+0.09	−0.01 +0.15
English Series II	−4.31*+0.31	−23.10*+2.08	−0.03 +0.08	+0.24*+0.11	+0.18 +0.12	−0.64*+0.21
English Series III	−3.42 +NA	−14.10 +NA	−0.17 +NA	+0.22 +NA	+0.33 +NA	−0.64 +NA

* Significant at 5% level, individual t-tests.
NA, standard deviation not available.

TABLE 9

Variance ratios and coefficients of variation of University of Hawaii Japanese women compared with U. S. college women (series I–VI pooled)

	Variance ratio		Coefficient of variation (standard deviation/mean)	
	U. S./U. H.	P	U. S.	U. H.
Height	1.85[1]	< 0.002	0.04	0.13
Weight	1.14	> 0.10	0.12	0.13
First component	1.50[1]	< 0.02	0.18	0.15
Second component	1.97[1]	< 0.002	0.28	0.17
Third component	1.15	> 0.10	0.35	0.35

[1] Significant at 5% level.

English men. They are also considerably more highly endowed in the second somatotype component, i.e., much more muscular and heavy-boned. This sample of men of Japanese ancestry shows a higher degree of second component dominance than any of several occidental series however selected or sampled. We infer therefore that a true ethnic difference in somatotype is established.

The women of Japanese origin also are seen to be shorter and lighter than American and English women of the same generation (and selection). They exhibit somewhat more first component dominance (fatness) than do the occidental women, but like the occidental women exhibit only in rare cases second or third component dominance, these, apparently, being traits linked more with sex than with ethnic origin.

In somatotype rating, despite the rarity of real second component dominance, the Hawaii Japanese women are more muscular than the American women but about the same as the English women, who, however, were specially selected (as games mistresses) for this trait.

The variances of the several series were examined and the Hawaii Japanese series seen to be more homogeneous (smaller variance) than the occidental series on most of the traits measured. This apparent difference in homogeneity is seen to be largely a matter of size, since *relative* variation shows negligible differences except on the second somatotype component, in which for both men and women the Japanese series have a rather small variance associated with a large mean and the occidental series have larger variances associated with smaller means.

The various series are compared each separately with the Hawaii Japanese series by use of individual t tests, analysis of variance procedures having been ruled out as inappropriate because of substantial heterogeneity of both sample variances and sample sizes. Significance tests for the inferences above were made at the 5% level but in nearly every instance the t value was so high as to leave little doubt of the reality of the difference.

Although a clear ethnic difference in somatotype as between Japanese and occidental men and women is evident, it is also noted that as between different series within the U. S. or within England, significant differences may also be observed if the series are fairly large. These within-ethnic category differences are generally very small in magnitude as compared with the between-ethnic category differences.

ACKNOWLEDGMENT

Grateful acknowledgment is made to Miss Virginia B. Berry of the Department of Public Health and Preventive Medicine, University of Oregon, Medical School, for her assistance with the statistical analyses.

LITERATURE CITED

Duncan, D. B. 1955 Multiple range and multiple F tests. Biometrics, *1:* 42.
Heath, B. H. Unpublished data.
Miller, C. D. 1961 Stature and build of Hawaii-born youth of Japanese ancestry. Am. J. Phys. Anthrop., *19:* 159–172.
Sheldon, W. H. 1954 Atlas of Men. Harper Bros., New York.
Sheldon, W. H., S. S. Stevens and W. B. Tucker 1940 The Varieties of Human Physique. Harper Bros., New York.
Snedecor, G. W. 1957 Statistical Methods, 5th ed., Iowa State College Press, Ames, p. 251.
Tanner, J. M. 1952 Physique of students. Lancet, *2:* 405–412.

Manned Space Flight Vehicles and the Physical Anthropologist

RICHARD G. SNYDER[1]
Applied Research Laboratory, College of Engineering, University of Arizona, Tucson, Arizona

The efforts to place Man in the new astroecological environment of space pose many problems for which limited knowledge, or in many instances no knowledge at all, exists. Engineering achievements which make space flight imminent demand advances toward solution of problems of physiology and anatomy, and have resulted in new areas of scientific study in space medicine such as bionics, gravics, and bioastronautics (or astrobiology).

We anticipate that a gradual lengthening of Man's exposure to the space environment will provide more positive information concerning some of these factors. The current series of X-15 flights will eventually take its pilot to the fringes of space for brief periods. To date two manned space capsule suborbital flights have been accomplished by United States astronauts poised on the tip of Redstone rockets and fired to a maximum altitude of 118 miles and at velocities to 5280 m.p.h. (Dryden, '61). Successive ballistic flights may be made at speeds up to 15,000 m.p.h. Information of a more advanced nature will be obtained from Dyna-Soar I, a manned hypersonic rocket-boosted glider which will penetrate a step further (Putt, '58). Meanwhile, Project Mercury may soon achieve its goal of sending a man about the earth in approximately three 90-minute orbits (Douglas, '60; Belieu, '59), a feat pioneered by the U.S.S.R.'s recent successful manned space flights. Successively more advanced programs are already in the preliminary and advanced design stages. Venus and Mars unmanned probes are planned within two years, and serious study is being given to requirements for manned-rocket missions to Mars or Venus (Enriche, '59; Dugan, '60; Smolek, '60; Himmel, '61). Within 5 years other projects propose to place a 4 to 6-man space laboratory in orbit between 300 to 400 miles out (Sweeney, '60). And within 10 years, Project Nova has as its objective lunar exploration and return to the earth of a 4-ton two- or three-man space vehicle (Rosen, '59).

Biological payloads are now becoming critically important (instead of secondary to instrumental payloads). During the past year a number of mammals have paved the way for manned flights. Among animals known to have successfully survived space flight for varying periods of time are mice ("Sally, Amy, and Moe," who rocketed to 700 miles above the earth in an Atlas nose cone in October, 1960), dogs (U.S.S.R.'s "Laika" in 1958 in Sputnik II, followed by some 20 rocket tests with rabbits and dogs in 1959, and more recently by "Belka" and "Strelka" in August, 1960, and "Pschelka" and "Mushka" in December, 1960), squirrel monkeys ("Able," "Baker," "Gordo," and "Sam"), and the chimpanzee "Ham" (February, 1961). Man himself has until recently nervously waited on the threshold, leading up to the current series of ballistic and orbital and future true space missions by simulating anticipated conditions through closed environmental studies, through extrapolation of animal research, and through brief balloon and aircraft flights to the fringes of the earth's stratosphere.

In the increased emphasis upon the unknown factor of Man himself, the anthropologist has much to contribute. In this paper I should like to note briefly some of the current and possible future areas of aerospace research concerning man, which should challenge and stimulate the physical anthropologist.

---

[1] The author is currently Chief, Physical Anthropology Branch, Department of Survival Research, Civil Aeromedical Research Institute, FAA, Oklahoma City, Oklahoma.

DISCUSSION

There is, of course, nothing new about either basic or so-called "applied" anthropological research in support of industrial, military, or governmental programs. Most physical anthropologists have at one time or another contributed toward solution of specific problems in these areas. A rather comprehensive discussion of military aspects of physical anthropological studies in the armed services has been previously published in the symposium entitled "Anthropology in the Armed Services" (Dupree, '58).

The recent formation of a Physical Anthropology Branch within the Department of Survival Research at the Civil Aeromedical Research Institute should be of interest in this respect. This new research organization of the Federal Aviation Agency is unique in that it represents the first civilian anthropological research group to be primarily concerned with the problems of aviation medicine. The new Civil Aeromedical Research Institute building, for which some 5½ million dollars have been appropriated, will contain three major physical anthropology laboratories, including an anatomy laboratory completely equipped for storage and dissection of cadavers and storage of tissues and organs under controlled humidity and temperature conditions, as well as associated laboratories and animal quarters. Current investigations already in progress or planned include application of such new experimental techniques as ultrasonic determination of body composition, use of implanted gamma isotopes for bone position monitoring, and other techniques. Studies will also be concerned with static and dynamic testing of bone or other body tissues in response to various forces, center of gravity, kinematics, somatotyping and anthropometrics of various populations, and other studies concerned with man in an aviation environment ranging from genetics to pathology.

Anthropometrics and biomechanics will remain important contributions of the aerospace anthropologist in design of flight garments and personal equipment, workspace design and area, and, of course, in selection of astronauts. While the concept of the "average man" both anatomically (Daniels, '52) and physiologically (Williams, '58) is a fallacy, astronau selection for future space projects will require a "maximum man" concept in mos respects except size. The present 5th to 95th percentile design criteria will give way to much narrower selections. Obviously selection of too large a man would involve serious design penalties, since weight and size of satellite or space vehicle are affected. In practice, it is probable that Dyna-Soar I may use a subject of about the 65th percentile, while the Project Mercury astronauts are in the 65th to 80th percentile in regard to stature (except for one Mercury candidate who is only 5 feet 7 inches and in the 20th percentile).

Aerospace biological problems

Aerospace problems come in a wide assortment of sizes and complexities. But where man is concerned many projects could benefit from advice by a competent anthropologist, whether they involve a question of how much heat a man can stand, decision of quadruped or primate for deceleration simulation of man, or other aspects of man's survival in a new environment.

Some of the aerospace medicine areas of concern which should be of interest to the anthropologist include those inherent in hypersonic escape, space capsule environments, seating and restraint, the phenomena of weightlessness and its implications, human tolerance to forces of acceleration, of vibration, of windblast, of tumbling, and of oscillation and displacement of internal organs; criteria of physique and body composition, recycling of wastes in nutrients, biological effects of ionizing radiation, and a vast array of other biological and cultural relationships. I will comment briefly on the role of physical anthropology in some of these research areas.

It is increasingly evident that current systems and concepts of restraint of aircrew members of present aircraft weapons systems are inadequate to meet the new problems imposed by greatly increased operational capabilities. Requirements for future protective devices and restraint sysems in manned space flight become even more complex.

The anticipated flight conditions associated with rocket flight which man must cope with include: saw-toothed acceleration during vertical launch as successive rockets fire in multi-stage propulsion systems, weightlessness, prolonged maneuvering accelerations, decelerations during re-entry into the earth's atmosphere, deviations from trajectory, separation of escape capsule from vehicle on launch pad during boost, flight instability, escape device parachute deployment, and finally capsule landings on either water or land environments.

Each of these operational maneuvers has associated forces against which man must be protected. Some of these conditions will include acceleration and deceleration multi-directional forces with often simultaneous lateral, horizontal and vertical components, vibration, oscillation and zero gravity.

Studies of human tolerance to various forces anticipated in space flight have generally been isolated and evaluated in single vector situations. Actually, man may be subject to several of those forces acting simultaneously from different directions, and tolerance to those more complex situations will require considerably more investigation.

Acceleration, the rate of change of velocity with respect to time, may be anticipated to be a major factor in Man's flight in space, particularly in regard to restraint design. Acceleration may be in the form of positive G, in which case the force vector acts parallel to the long axis of the body (known in Air Force terminology as "eyeballs in"), in head-to-foot negative G (the force vector acts parallel to the long axis of the body, from foot to head), or transverse G (in which case it may consist of either prone or supine force vectors, i.e., chest to back, or back to chest). In addition, lateral G forces may act from side to side. It is quite probable that man may be subject to two or more of these accelerations simultaneously. The phenomenon of rapid deceleration, in particular, may produce undesirable physiological or anatomical trauma which must be taken into consideration in restraint design.

In the case of transverse accelerations, it has been found that when the human pain threshold occurs at above 10 G for 10-second exposures, moderate tachycardia and distracting epigastric pain may develop (Lambert, '45). This can be relieved considerably if the seat is designed to hold the pilot in the correct position at all times; thus a mechanism to rotate the seat and reorient it to changing flight conditions may be advisable. In the Mercury capsule, a method of 180° seat rotation has been devised so that the resultant inertial force from acceleration acts in the same direction during both initial boost and terminal re-entry. Man's physiological tolerance and functional ability during the acceleration phases of space flight are important factors in the basic design of the human support-restraint system. A useful approach is the principle of net support originated by Hertzberg ('48) at WADD some 12 years ago, because of its weight, support, and comfort advantages.

Negative G forces (foot to head centrifugal forces, or "eyeballs up") can be tolerated up to 2 G for three minutes. However, in exposures above 2 G time rapidly decays; at 3.5 G, it should not exceed 10 seconds since the heart and blood vessels are no longer able to maintain normal circulation, the pressure of the internal organs upon the chest hampers respiration, and hemorrhaging of vessels in the face and temple occurs (Freitog, '53). Effects of prolonged angular accelerations have been studied within the past year by several investigators in respect to the torsion pendulum theory (Guedry and Ceran, '59), and motor activity (Suvorov, '59). Much of the physiological and anatomical knowledge is supported by evidence obtained in animal rocket shots in studies of the effects of launch and re-entry, utilizing rodents and various species of primates.

Recent investigations of the water-landing impact of a 1172-pound manned orbital capsule has shown that maximum accelerations of 60 G with a 25,000 G/sec. rate of onset may be expected. The horizontal velocity may exceed 14 ft./sec. at impact with a simultaneous vertical velocity of 30 ft./sec. (Hatch, '59). It is interesting to note that Stapp ('60) found that in rocket sled transverse decelerations a chimpanzee subject has survived a peak of 237 G with 11,250 G/sec. rate of onset and 0.35 sec. total exposure duration. Transient injury effects in chimpanzees were observed at 60 G at higher than 5000 G/sec. rate of onset transversely. Some organs present more complex protection problems than others. For example, the 10–12 oz. adult human heart, while relatively restricted in transverse movement, has been displaced laterally to the limits of the thoracic cavity by forces of only 10 G (Dempsey, '61).

Impacts of 100 G are possible in land contacts of a manned flight capsule, although the initial Mercury flights are designed for re-entry in the area of the Atlantic Ocean between Florida and the Canary Islands (Donlon, '60). In the current configuration the distance required to stop within the apparent tolerable limits for man (1,500 ft./sec. for 40 G for 0.2 sec. duration (Stapp, '58) or 600 ft./sec. for 40 G for 0.2 sec. (Stapp, '60) is a minimum of 8.54 inches. Actual conditions in a capsule impact landing may be even higher if the velocity component is increased, as would occur if the parachute drag failed, and furthermore local meterological conditions such as wind-drift may cause complex multi-directional patterns. For example, 20 mph winds can result in horizontal loads as great as the vertical component.

Numerous investigations of deceleration effects on the human body have been conducted, and to date considerable knowledge is available as to the force man can tolerate. However, the area of plastic or nonreversible injury is still only loosely defined from the anatomic and physiological viewpoint. Stapp ('55) reported that the value of 50 G for human tolerance (with rate of onset below 500 G per sec. for 0.25 duration) and 100 G for survival, on the basis of animal experiments, may be a conservative estimate in view of data concerning falls survived, which have been as great as 209 G (DeHaven, '42). Swearingen ('60) has successfully subjected volunteer male subjects to vertical impact loadings of 250 G's in vertical drop tests, with knees flexed between 100–160 degrees, and as high as 65 G's with knees rigid. He has found the area of non-reversible injury to be at about 95 G's (.007 secs. at 19,000 G/sec. rate of onset) whil seated in a rigid chair. More recent vertical free-fall studies by Snyder ('61) of individuals who have survived accidenta free-falls or suicide attempts of distance up to 275 feet, indicate survivable limit (beyond the injury threshold) may be many times these loadings provided the time durations are very short (about .005 secs.).

A major problem confronting space scientists currently is the need for a new concept in restraint which will take into consideration protection of the occupant from each of these forces discussed. Any restraint system for future manned space flight vehicles must fulfill a number of requirements of a rather complex nature. The simple lap-belt and shoulder harness configuration of today's aircraft often are inadequate protection for ejection (Levy, '61; Snyder, '59) or crash forces (Hasbrook, '60; Swearingen, '61; McMichael, '61; Stapp, '61), and would be of little value in the space environment. To illustrate this point, the following design requirements are listed for a basic minimum restraint system.

1. It must provide maximum comfort for extended periods, yet the system must be of minimum weight.
2. Complete freedom of body movement during normal flight must be incorporated.
3. The restraint must be designed to provide widest possible body distributions of accelerative forces.
4. It must provide operational dexterity, with carefully designed release for both manual and automatic operation.
5. Positioning and immobilization must be automatically sensed and accomplished at a predetermined level of acceleration. What level is desirable?
6. The restraint must give lateral and vertical support of the upper torso as well as horizontal support, as in a crash landing, or drift of a landing capsule.
7. The design must be compatible with vehicle crew stations and escape systems.
8. It must have the capability to retract the crewman into the capsule prior to capsule activation and continue restraint

within the capsule, necessitating a separate power source.

9. Not only the body, but the extremities and head must be restrained to prevent flailing and injury.

10. Attention must be given to the attenuation of vibration (5–2000 cps).

11. The components must be integrated to minimize encumbrance on the crewman, thus the system must be as simple as possible.

12. There must be adequate angularity adjustment to place the crewman in the optimum position for predicted accelerations, as in launch or re-entry situations.

13. The design must incorporate energy absorption devices to provide sufficient protection against anticipated high impact loads.

These problems have necessitated a fresh approach to the concept of seating and restraint, and currently the Air Force, National Aeronautics and Space Administration, industrial, and various private research groups are exploring new ideas in this area.

Another important area where the anthropologist could contribute greatly is to that of fundamental research relating to better anthropomorphic simulation. Anthropomorphic, and even chimpomorphic, dummies are utilized extensively in all types of experimental research where initial use of human subjects might prove dangerous, to probe beyond human tolerance limits, or to save expense in a test program. Dummies are being used for nearly every conceivable type of aerospace research, including flight-testing of escape systems, crash research, blast effects studies, tests of frogman's gear and windtunnel personnel equipment tests. However, until more basic research can point the way to more reliable simulation, the usefulness of anthropomorphic dummies for research purposes will continue to be more restricted than necessary. Applicable information is needed concerning muscle and ligament simulation, the properties of intervertebral discs, flesh characteristics, and other questions such as the dampening of force along the vertebral column. What effects do torsion forces have? As yet there is no anthropomorphic dummy which has a fully articulated verteral column, for example, due to a lack of basic data. Obviously anthropomorphic dummies cannot fulfill their widest research application until more precise and valid simulation is attained.

A phenomenon which has received considerable attention recently is that of weightlessness (also variously known as null or sub-gravity, zero W, zero gravity, or the agravic state). This is a gravity-free, thus weightless condition which has been found to exist during rocket flight, and is assumed will exist upon a space station or satellite which would orbit about the earth.

It is important to man's conquest of space because of the effects of loss of vestibular sensation and change of proprioceptive sensation, on functional ability. Exposure in experimental studies to date have shown that this often results in illusions, disorientation, and discoordination. If deprivation of vision and either vestibular or kinesthetic input occurs, orientation is lost.

In short duration human experiments in aircraft, water, and subgravity devices, Gerathewohl ('60) notes that detrimental effects have been found to include a disturbance of the neuromuscular coordination, disorientation without visual reference, prolonged blackout and delayed motor responses during post-acceleration weightlessness, motion-sickness symptoms, a mental set for falling, and oculo-agravic illusions in the dark. However, he also reported that subjects appear to adapt and compensate during exposure, to move more easily than normal and do learn to perform as under 1 G conditions. The longest exposure to date that has been reported is that of the dog in Sputnik II which endured 6 days of weightless flight with no significant physiological changes.

Among the physiologic problems induced during this state, are the mechanisms of nourishment, including deglutition and manual conveyance of liquids and solids to the mouth. Food bulk will be important in preventing constipation. However, a large solid bolus of food is a potential aspiration problem, and regurgitation of stomach contents will certainly be a serious annoyance. The intake of large amounts of liquids may also induce vomiting (Ward et al., '59). Thus, nausea, vertigo, confusion, and hallucinations, can all contribute to Man's discomfort and seriously disrupt his effectiveness during extended periods of weightlessness.

It has also been found that alternations of acceleration and the weightless state decrease the acceleration tolerance of the subject and the efficiency of the physiological recovery mechanisms. This implies that for manned space flight thrust values and re-entry profiles must take the lower acceleration tolerance into consideration, and also adequate G-protection must be designed for the pilot to prevent injurious effects of high decelerations. The hazard in re-entry, due for example, to failures of the automatic guidance system could produce excessive G-loads which would subject the occupant to severe accelerations due to continuously changing direction, rate of onset, magnitude, and duration. Von Beckh ('58), Clarke ('59), and others, have advised the investigation of a multi-directional G-restraint device which would avoid G-loads in the unfavorable spinal axis by automatic positioning of the occupant.

Another aspect, that of biomechanics under partial or zero gravity is of particular importance to the anthropologist. Hertzberg ('60) Dzendalet ('60), and others have recently pointed out some of the problems and pitfalls man may encounter in construction of space stations. Each action must be carefully considered in advance because in a gravity-free environment some quite normal actions and movements, such as riveting, would be impossible.

A problem man will face while under zero-gravity conditions is that of initiating self-locomotion. One solution currently under study is the use of magnetic shoes or sandals to enable the wearer to walk in a normal manner while weightless. This will require an analysis of the forces required in normal walking, since the use of magnetic shoes or sandals may change the pattern of walking under zero-gravity. One may have to "learn" how to walk. Such shoes must be designed with holding capabilities in excess of the accelerations expected during the mission. It has been suggested that a magnetically fixed component should have a functional force great enough to compensate for increased accelerations, requiring auxiliary magnetic systems for emergencies (Simons, '59). For example, a space vehicle may be equipped with collision-avoidance equipment which would program automatic rapid acceleration to prevent collision with meteorites.

Some investigators have suggested the creation of partial gravity induced by space ship rotation for easier living conditions for man in space. In this regard the determination of the optimum G-load condition for Man may be dictated by motor performance factors.

A number of methods have been used with variable success to achieve or simulate weightlessness, although the time factor is still too small for extended observations. This is often done by immersion of the test subject in a fluid of equal specific gravity, or use of an underwater test table in a swimming pool, or underwater pressurized chamber. The use of a water filled tank with the human subject suspended in the water, and rotating about a horizontal axis is also being investigated for long periods of simulation (Levine, '60). However, the most extensive experiments have been conducted utilizing aircraft flown in a parabolic flight arc or Keplerian trajectory in which centrifugal force would exactly offset the downward pull of gravity (Ward, '57). Aircraft flights can achieve a zero partial gravity condition for periods up to 90 seconds, although the X-15 should be capable of a 5-minute period. The longest weightless period achieved thus far with a primate is 13.3 minutes, and produced no significant physiological changes in a one-pound squirrel monkey ("Gordo") fired 300 miles into space in an Army Jupiter ballistic missile nose-cone (Anonymous, '59). Weightlessness is likely to be encountered in manned flight vehicles in varying degrees of positive or negative forces for greater time periods than in the true null gravity state. For example, out of 30 seconds of less than + 0.1 G obtained in the F-94C, only 7 seconds of it is consecutively zero G. In an orbiting satellite of finite size the completely gravity free state, or full balance of centrifugal and gravitational forces, is realized only at the center of gravity of the vehicle (Schaeffer, '59). This means that objects toward the edges must be tied together or they may tend to float apart. Another important point is that it has been found that 30 seconds of zero-G are required before the vestibular apparatus reacts as it will to stimuli in orbit.

However, it should be noted that at least one investigator, Professor Margaria ('53, '59) of the Institute of Human Physiology of Milan, believes that the disadvantages of the weightless condition have been overemphasized, and that in reality the lack of gravity will be a great asset, since circulation of blood and fluids would be greatly facilitated if the hydrostatic pressure did not have to be met with, as well as considerable savings of mechanical work normally involved in giving acceleration to the muscles and solid portions of the body in overcoming friction.

The physical response of man to the effects of mechanical forces such as extreme buffeting and vibration is another area of activity. Effects of frequency and amplitude are influenced by such factors as direction of the vibration in relation to the body axis, bone and other body tissue conductivity, and amount of body area in contact. Vibrations are an important factor in aircraft and space vehicle flight because vibration with an amplitude greater than 0.008 inch or 1500 cps tense the musculature and cause discomfort and "fatigue" (Armstrong, '52). Thus, methods attenuating or damping such effects through seat cushions and other means are being studied.

Some anthropologists are working in an interdisciplinary area concerned with human factors, and its more sophisticated cross-cousin, systems engineering. This field essentially is concerned with the relationship of man in a specific environment as part of a complex machine system. Engineers have gradually realized that human tolerances and capabilities must be taken into consideration prior to design of any system, in order to obtain optimum efficiency from the equipment. Nowhere is the fact that man is the "weakest link" more evident than in space flight.

Even in infinitely simpler situations than man may be expected to encounter in space flight, errors are continually made for which careful safeguards have been provided. In this regard, for example, one of the oldest human failures in aviation is the situation in which the pilot neglects to lower the landing gear in landing. Yet occasionally an impressive number of warnings designed specifically to appeal to all of man's senses appear to have no effect. Recently, a British BOAC Comet IV commercial jet airliner was accidentally landed gear-up at Rome, despite the presence of three other crew-members assisting the pilot, a panel of red lights, an alarm in the headset, both touch and visual means of checking the gear up-down indicators and gear handle, a required visual gear check, and a verbal before-landing check-list by the co-pilot. "Human factors" may be confidently predicted to remain a problem.

Extraterrestrial exploration will certainly be of value to the anthropologist. Clark Randt, ('60) Director of the National Aeronautic and Space Administration's new Office of Life Sciences, has recently noted that "the basic study of extraterrestrial environments is ultimately likely to be most productive in furthering an understanding of the fundamental laws of nature. Among the most perplexing questions which have challenged Men's minds are the nature and origin of life and the possibility of its presence in the universe other than on the earth alone. For the first time in history, partial answers to these questions are within our reach." Certainly since 1609 at least, when Galileo Galilei built the first astronomical telescope and confirmed the hypothesis of Copernicus that the sun is the center of our universe, man has speculated on the possibility of extraterrestrial life.

Although only the still unseen, but gravitationally demonstrated, planet orbiting 61 Cygnus is the sole recognized planet known to Man outside our solar system, Shapley ('60) has calculated that there are not less than 10^{21} stars capable of "radiating the energy necessary for synthesis of the animate out of the inanimate" and that our galaxy is but one of billions in the universe we know.

However, it has only been within the past 7 years that the biologist has been able to obtain sufficient basic ecological data concerning certain other known planets of our solar system to consider this problem seriously. Strughold in 1953 made the first physiological study of the possibility of life on Mars, confining himself to known manifestations of life as found on this planet. Due to the fact that Mars apparently has a terrestrial environment similar to that of earth at 56,000 feet altitude, it was concluded that man, properly equipped, could survive there. Yet, it would be very unlikely that other forms of life as we know it higher than lichens or bacteria could be native to the Mars environment, and this has been confirmed in three recent laboratory simulations of growth in a Martian environment (Davis et al., '59; Kooistra et al., '58; Vishniac, '60). Beyond this we can only speculate.

SUMMARY

This paper has briefly considered a number of the current major aerospace research areas which are of prime interest to the physical anthropologist. While the areas of human tolerance studies and problems in future manned space flight restraint systems have been emphasized, it should be noted that there are many other areas of equal importance which could benefit and in some cases are benefiting from anthropological knowledge and techniques. No mention, for example, has been made of the social relationships implicit in the inhabiting of a confined area for extended periods of time (although the implications of this have not been missed by science fiction writers), nor of the long-term effects of various types of radiation upon the human organism.

In conclusion, it seems apparent that the discipline of physical anthropology can be of particular value in current and future aerospace medical research. Certainly no other area of study has inherent in its structure such a comprehensive range of knowledge concerning man.

LITERATURE CITED

Armstrong, H. G. 1952 Principles and Practice of Aviation Medicine. Williams and Wilkins, Baltimore, p. 453.

Barr, N. L. 1958 Few physiological changes noted in monkey's weightless flight. Aviation Week, *69:* 23.

Belieu, K. E. 1959 Project Mercury: man-i space program of the National Aeronauti and Space Administration. Report of the Cor mittee on Aeronautical and Space Science U. S. Senate, 86th Congress. 1st Session Rep no. 1014.

Clarke, N. P., and R. N. Headley 1959 Studi of primate tolerance to some complex acceler tions. WADC Tech Rept. no. 59–630.

Daniels, G. S. 1952 The average man? Ae Medical Laboratory, WADC. Report no. 53–

Davis, I., and J. D. Fulton 1959 Microbiolog studies on ecologic considerations of the ma tial environment. Aeromedical Reviews, 2–6

DeHaven, H. 1942 Mechanical analysis of su vival in falls from heights of fifty to on hundred and fifty feet. War Medicine, *2:* 586 596.

Dempsey, C. A. 1961 Human protection i abrupt acceleration environments. 1961 Proc Institute of Environmental Sciences. Wash ington, D. C. pp. 365–370.

Donlon, C. J. 1960 Project Mercury. Psych physiological aspects of space flight, Symp sium, School of Aviation Medicine, USAF Aer space Medical Center, Texas, 26 May.

Douglas, W. K. 1960 Mercury pilot's orbita role described. Aviation Week and Spac Technology, *72:* 53.

Dryden, H. L. (chairman) 1961 Proceeding of a conference on results of the first U. S manned suborbital space flight. June 6, 1961 United States National Aeronautics and Spac Administration, National Institutes of Health and National Academy of Sciences. Washing ton, D. C.

Dugan, J. F. 1960 Analysis of trajectory pa rameters for probe and round-trip missions t Mars. National Aeronautics and Space Admin istration Rept. TN D-281.

Dupree, L. (ed.) 1959 Anthropology in th Armed Services: research in environment, phy sique and social organization. Social Sci. Res Center, The Pennsylvania State University.

Dzendalet, E. 1960 The ability to apply force while tractionless. 1961 Proc., Institute o Environmental Sciences. Washington, D. C. pp. 365–370.

Enriche, K. 1959 A systems analysis of fas manned space flights to Venus and Mars. Par I, Convair-Astronautics Rept. No. AZM-072.

Freitag, W. 1953 Untersuchungen über die Wirkung von Fliehkraften in Richtung Fuss Kopf auf den menschlichen Organismus Ztschr. Flugwissenschaft, (Braunschweig), *1* 25–30.

Gerathewohl, S. J. 1960 Weightlessness. Ma in space: the United States Air Force Program for Developing the Spacecraft Crew. K. F. Gantz, ed. Duell, Sloane and Pearce, N. Y. p 121.

Guedry, F. E., Jr., and S. J. Ceran 1959 Derivation of subjective velocity from angular displacement estimates made during prolonged angular accelerations: adaptation effects. Army Medical Research Lab. Rept. 376.

Hatch, H. G. 1959 Effects of water-landing impact on an orbital capsule from the standpoint of occupant protection. Langley Res. Cntr. Rept. D-39.

Hasbrook, A. H. 1960 "Crash-safe" design can make many accidents survivable. space aeronautics. Sept., pp. 79–87.

Hertzberg, H. T. E. 1948 A prone position bed for pilots. USAF Mem. Rept. MCREXD-695-71D. Aeromed. Lab., WADC, Dayton.

——— 1960 The biomechanics of weightlessness. Aircraft and Missiles, in press.

Kooistra, J. A., and others 1958 The behavior of microorganisms under simulated Martian environmental conditions. Pub. Astron. Soc. Pacific, *70:* 64–69.

Lambert, E. H., E. H. Wood and E. J. Baldes 1945 Man's ability to withstand transverse acceleration when in the sitting position. National Research Council, Division of Medical Sciences. Rept. No. 418, pp. 1–3.

Levine, R. B. 1960 Null gravity simulation. Lockheed Aircraft Corp., ORD 232.

Levy, P. M., D. J. Sekinger and R. S. Stone 1961 A discussion of the nature and source of injury experienced by aviators ejecting from F9F-8T Cougar utilizing MK-A5 seat. Symposium on Biomechanics of Body Restraint and Head Protection. Office of Naval Research. June 14–15, 1961 (in press).

Margaria, R. 1953 La condizione di subgravita e la sottrazione dall' effetto delle accelrazion. Revista Med. Aero, *16:* 469–474.

——— 1958 Wide range acceleration investigations in man and animals. Ibid., *21:* 655–690.

——— 1959 Spatial flight physiology. Scient. Med. Ital., *7:* 605–637.

McMichael, H. 1961 Injury patterns as seen in material from aircraft accidents available at the armed forces institute of pathology. Armed Forces Institute of Pathology, Washington, D. C. (in press).

Putt, D. L. 1958 Inquiry into satellite and missile programs. Hearings before the Preparedness Committee on Armed Services. U. S. Senate, 85th Congress, 1st and 2nd Sess., pt. *2:* 2031.

Randt, C. T. 1960 Space research in life sciences. Part I. Aviation Week and Space Technology, *72:* 50–56.

Rosen, M. W., and F. C. Schwenk 1959 Nova—a manned lunar rocket. Astron., *4:* 20–23, 96–97.

Schaeffer, H. J. 1959 The gravity-free state on a space platform. Armed Forces Med. J., *10:* 1308–1323.

Shapley, H. 1960 Extraterrestrial life. Astron., *5:* 32–33, 50–52.

Simons, J. C. 1959 Walking under zero gravity conditions. WADC Tech. Note 59–237.

Smolek, G. R., and R. H. Knoll 1960 Cryogenic Propellant storage for round trips to Mars and Venus. Institute of Aeronautical Sciences paper No. 60–23.

Snyder, R. G. 1959 A new approach to the problem of increasing human tolerance to high deceleration forces. J. Arizona Acad. Sci., *1:* 68–71.

——— 1961 unpublished data.

Stapp, J. P. 1955 Tolerance to abrupt deceleration. Collected Papers on Av. Med., pp. 122–139.

——— 1958 Accelerations of Space Flight. Am. Rocket Soc., pp. 1–10.

——— 1960 Human Tolerance to Accelerations of Space Flight. In: Physics and Medicine of the Atmosphere and Space. O. O. Bensen and H. Strughold, eds. John Wiley and Sons, N. Y. p. 473.

Stapp, J. P., S. E. Neely and A. B. Nutt 1961 Crash protection of air transport passengers. Presented at Aerospace Medical Association annual meeting, Chicago. May.

Strughold, H. 1953 The Green and Red Planet: A physiological Study of the Possibility of Life on Mars. Univ. of N. Mex. Press, pp. 47–66.

Suvorov, P. M. 1958 Effect of angular acceleration on the secretory and motor activity of the human stomach. (Vliianie radial'nykh uskorennii na sekretsiiu i motornuiu deiatel'nost' zheludka u cheloveka). Biulleten' Eksperimental 'noi biologii i meditsiny (Moscow), *45:* 14–16. May 1958. Translated in: Bull. Exper. Biol. Med., *45:* 531–532, 1958.

——— 1959 Effect of angular acceleration on the secretory and motor activity of the human stomach. A.M.A. Proc.

Swearingen, J. J., E. B. McFadden, J. D. Garner and J. G. Blethrow 1960 Human voluntary tolerance to vertical impact. Aerospace Med., *31:* 989–998.

Swearingen, J. J., A. H. Hasbrook and R. G. Snyder 1961 Kinematic behavior of the human body during deceleration. Aerospace Med. (abstract), *32:* 249, (in press).

Sweeney, R. 1960 Manned orbital laboratory proposed. Aviation Week and Space Technology, *72:* 37.

Vishniac, W. 1960 Extraterrestrial microbiology. Symposium of Bioastronautics, Aerospace Med. Assoc. Ann. Meeting, May.

von Beckh, H. J. A. 1958a Flight experiments about human reactions to accelerations which are followed or preceded by the weightless state. Aerospace Med. Field Lab., N. Mex.

——— 1958b Physiology of launching and reentry stress in rodents. AFMDC TN no. 58–11. Aeromed. Field Lab., N. Mex.

Ward, J. E. 1957 Requirements for present-day experimental zero gravity parabolas. USAF School of Aviation Med., Rept. 57–121.

——— 1959 Physiologic response to subgravity. Ibid., Rept. 59–2.

Williams, R. J. 1958 Biochemical Individuality. Univ. of Texas Press.

The Blood Groups of the Pastoral Fulani of Northern Nigeria and the Yoruba of Western Nigeria

B. S. BLUMBERG, ELIZABETH W. IKIN AND A. E. MOURANT
National Institute of Arthritis and Metabolic Diseases, National Institutes of Health, Bethesda, Maryland and The Blood Group Reference Laboratory, The Lister Institute, London, England

The Fulani are one of the largest tribal groups of Africa, spread over nearly half its width, from Senegal in the west to Wadai, east of Lake Chad. In part they are settled town dwellers who, as a result of vigorous military and political action before and shortly after the arrival of the Europeans, became the ruling class in several areas of West Africa. The town dwellers have, in general, intermarried with the groups they governed and, to a large extent, forgotten or abandoned many of their ancient customs and their language. The seminomadic "cow" Fulani, who still follow their ancient pastoral life, have remained more aloof from their neighbors and, to a large extent, retained the Fulani language and customs (de St. Croix, '45).

There has been a great deal of conjecture as to the affinities of the Fulani, and several theories of Caucasoid origin have been advanced. Delafosse (with very little evidence) considers them a group of Aramaic-speaking Judeo-Syrians who entered Negro Africa from Cyrenaica about 200 A.D. (quoted in Greenberg, '49). However, Greenberg ('49) has shown that their language does not belong to the Hamito-Semitic group but closely resembles Serer-Sin (a language spoken in Senegal) and has a more remote connection with Wolof—a language spoken in the same region and elsewhere in West Africa. This places it in the northern sub-group of Westermann's West Atlantic section of the West Sudanic family, or in the westernmost branch of Greenberg's Niger-Congo group, neither of which is a Hamitic language group (Greenberg, '49). The Fulani are known by other names in other regions of West Africa, Foulah, Peul, Foul-be, etc., and anthropological and other differences may exist between these populations. Blood group studies have been reported on some of these populations but none, to our knowledge, on the nomadic Fulani of Nigeria (Koerber, '47; Koerber and Linhard, '51; Kossovitch, '34; de Lestrange, '49; Moullec and Linhard, '55; and Trincão, '53).

The Yoruba are the dominant tribal group in western Nigeria, and enclaves of Africans of Yoruba descent who still maintain some of their customs are found in Brazil and Cuba (Verger, '55). Blood specimens were collected from the Yoruba for studies reported elsewhere (Allison, Blumberg and ap Rees, '58; Steinberg et al., '61), and blood group tests were done on these specimens for comparison with previously published data. Previous blood group tests on the Yoruba have been reported by Muller ('27), Garlick ('57), Garlick and Barnicot ('57) and Chalmers, Ikin and Mourant ('53), most of whose South-west Nigerians were Yoruba.

MATERIALS AND METHODS

Blood was collected in "venules" (Winthrop Products, Ltd.), allowed to clot, refrigerated at approximately 4°C, and sent by air to London for blood typing. The tests were completed within three to 7 days of collection, and all bloods were deemed satisfactory for typing. Tests were carried out for the following antigens: A_1, A_2, B, M, N, S, Henshaw, P_1, C, c, C^w (all negative), D, D^u, E, e, V, K. All specimens were also tested for Lu^a, all with negative results, and for Fy^a, with only one positive result among the Fulani. In view of the known difficulty in testing specimens for the last two antigens when they are several days old, and in the absence of adequate positive controls, these results have not been included in the tables. Fifty-nine Yoruba specimens were tested for the Diego (Di^a) antigen, all with negative results.

Fulani. The Fulani bloods were collected in two groups. The first group consisted of 89 specimens collected by one of the authors (BSB, collection 1). These included 74 from Rimi and Kakio villages, both near Kaduna, Northern Nigeria, and 15 from visiting herdsmen in the market place at Gasawaba, Northern Nigeria. The second group consisted of 59 bloods for which we are indebted to Dr. Hayhurst, Medical Officer at Pankshin, (collection 2). These were collected from Pastoral Fulani from the region near Pankshin, Northern Nigeria. The samples were unselected as to sex and age. It was at first intended to treat these groups together, but it was found that they differed markedly in their MNS phenotype frequencies. After considering treating them as completely separate populations, it was finally decided to perform separate calculations upon their MNS groups but not to separate them otherwise. One reason for this decision was the large number of Rh phenotypes detected by means of the antisera used, including anti-V: as a result separate treatment would have meant that the numbers of each phenotype within each population would have been unduly small for statistical treatment.

Yoruba. One hundred and thirty-five bloods were collected from unrelated individuals in the village of Ilora, near Ibadan, in the western region of Nigeria. The majority (approximately 85%) of the subjects were school children, but some adults were included and the sexes were about equally represented. Gene frequency calculations were performed by the methods described by Mourant ('54). From the gene frequencies, the expected frequency of each phenotype was calculated, and from this the expected absolute number. Comparison with the number originally observed gave a value of χ^2 for that phenotype. Expected numbers less than 5 were combined for this purpose. The total value of χ^2 taken in conjunction with the number of degrees of freedom gave the probability of such a distribution in a random sample. χ^2 values are not given for tables 3 and 9 because of the small numbers in some of the groups.

RESULTS AND DISCUSSION

The results of our tests, and gene frequencies calculated from them, are shown in tables 1 to 11. In tables 4 and 9 the method used for representing the Rh phenotypes is that proposed by Mourant ('49), the presence or absence of the V antigen being expressed on exactly the same lines as for the other antigens, by V or vv. Most of the comparative data discussed below will be found tabulated, set out in maps, and discussed in Mourant ('54), Mourant, Kopec and Domaniewska-Sobczak ('58) and Roberts, Ikin and Mourant ('55).

Fulani. As already stated, the two batches of Fulani are treated separately as far as their MNS blood groups are concerned. Those of collection 2, though small in number, show a particularly high frequency of the N gene, which suggests a relationship with the Berber and Tuareg populations to the north (Messerlin and Lohro, '51; Jacquemin, '52; Barnicot, Ikin and Mourant, '54). The high O frequency in the same batch supports this suggestion, as do the Rh frequencies in both batches, for CDe is considerably higher and cDe lower than in any other African populations so far tested from south of the Sahara other than the Tuaregs. However, the frequency of the d gene (all as cde) is about that usually found in Africans and nowhere near the high figure found in Berbers and Tuaregs. This is compatible with a Mediterranean rather than a Berber admixture. The frequency of 45% of cDe chromosomes is, however, consistent with the thesis that these populations are in the main of Negroid origin.

The only other available data on the MNS and Rh groups of the Fulani (apart from 11 individuals included among the "Northern Nigerians" by Chalmers, Ikin and Mourant, '53) are an unpublished series by Garlick, Ikin and Roberts. These have a cDe chromosome frequency of 55% and thus appear to be more negroid than either of the present series. A higher cDE frequency of 10% suggests connections with other Nigerian tribes and with the

TABLE 1

The A_1A_2BO groups of the Fulani

Group	Number observed	Frequency observed	Frequency expected	Number expected	χ^2
O	82	0.5541	0.5381	79.64	0.0699
A_1	24	0.1622	0.1582	23.41	0.0147
A_2	8	0.0541	0.0753	11.14	0.8869
B	26	0.1757	0.1932	28.59	0.2345
A_1B	3	0.0203	0.0232	3.43	1.4897
A_2B	5	0.0338	0.0121	1.79	
Total	148	1.0002	1.0001	148.00	2.6957

Gene frequencies

P_1	0.0952
P_2	0.0496
q	0.1216
r	0.7336
Total	1.0000

TABLE 2

MNS groups in Fulani

Collection 1; 89 specimens sent by Dr. Blumberg

Phenotype	Number observed	Frequency observed	Frequency expected	Number expected	χ^2
MMS	11	0.1235	0.1223	10.89	0.0011
MsMs	12	0.1348	0.1333	11.86	0.0015
MNS	13	0.1461	0.1473	13.11	0.0009
MsNs	31	0.3483	0.3526	31.38	0.0047
NNS	1	0.0112	0.0112	1.00	0.0028
NsNs	21	0.2360	0.2332	20.75	
Total	89	0.9999	0.9999	88.99	0.0110

Chromosome frequencies

MS	0.1405
Ms	0.3651
NS	0.0115
Ns	0.4829
Total	1.0000

TABLE 3

MNS groups in Fulani

Collection 2; 59 specimens sent by Dr. Hayhurst

Phenotype	Number observed	Frequency observed	Frequency expected	Number expected
MMS	3	0.0508	0.0197	1.16
MsMs	8	0.1356	0.0538	3.18
MNS	2	0.0339	0.0888	5.24
MsNs	8	0.1356	0.3065	18.08
NNS	7	0.1186	0.0949	5.60
NsNs	31	0.5254	0.4362	25.74
Total	59	0.9999	0.9999	59.00

Chromosome frequencies

MS	0.0391
Ms	0.2320
NS	0.0683
Ns	0.6605
Total	0.9999

TABLE 4

The Rh groups of the Fulani

Phenotype	Number observed	Frequency observed	Frequency expected	Number expected	χ^2
ccDeeV	36	0.2432	0.2607	38.59	0.1733
ccDeevv	24	0.1622	0.1481	21.92	0.1969
CcDeeV	26	0.1757	0.1530	22.65	0.4965
CcDeevv	35	0.2365	0.2350	34.79	0.0013
ccDEeV	3	0.0203	0.0198	2.93	0.8027
ccDEevv	2	0.0135	0.0304	4.50	
CCDeevv	10	0.0676	0.0825	12.20	0.3982
ccD^{u}eeV	2	0.0135	0.0136	2.02	0.4877
CcDEevv	4	0.0270	0.0213	3.16	
ccDEEvv	1	0.0068	0.0014	0.20	
ccddeeV	2	0.0135	0.0147	2.18	0.0004
ccddeevv	3	0.0203	0.0194	2.86	
Total	148	1.0001	0.9999	148.00	2.5570

Chromosome frequencies	
CDev	0.2872
cDEv	0.0372
cDeV	0.1872
cDev	0.2701
cD^{u}eV	0.0338
cdeV	0.0454
cdev	0.1391
Total	1.0000

TABLE 5

The P and Kell groups of the Fulani

P_1^+	141	K+	1
P_1^-	7	K−	147

TABLE 6

The Henshaw groups of the Fulani

MNS phenotype	He+
MMS	0
MsMs	0
MNS	0
MsNs	1
NNS	1
NsNs	0
Total[1]	2

[1] Out of 148 tested, and listed in tables 2 and 3.

Belgian Congo. The MNS frequencies are intermediate between the two present series but the rather high N supports the theory of Berber admixture in the Fulani. The ABO frequencies also are intermediate between those of our two series in most respects. A fuller comparison will be made with the present data when the new material is published.

Results of previous tests on the ABO groups of the Yoruba show a high degree of consistency. The present results show a higher frequency of B, but the excess (of B+AB) is not quite significant statistically ($\chi^2 = 3.69$, $P > 0.05$).

The only published results of Rh and MNS tests on Yoruba are those of Chalmers, Ikin and Mourant ('53) whose "South-western Nigerians" were mainly Yoruba (102 out of 145). The present results differ little from these for the MNS system, and for the Rh system the main difference consists in a lower frequency of cDE in the present series, with a chromosome frequency of 1.1% as compared with 8.3% for the series of Chalmers et al. ('53). Dr. Ada Kopeć has kindly extracted the figures for Yoruba alone from the combined data of Chalmers et al. ('53), and calculated chromosome frequencies: that of cDE is 7.35%. Chalmers et al. ('53) found higher frequencies of cDE than this in all the other Nigerian populations examined and the frequency is high also in the Belgian Congo.

The frequencies of the Henshaw antigen, 1.4% in the Fulani and 2.2% in the Yoruba, are near to those found previously in Nigeria. The present data, taken by themselves, give little information as to

TABLE 7

A_1A_2BO groups of Yoruba

Group	Number observed	Frequency observed	Frequency expected	Number expected	χ^2
O	60	0.4444	0.4414	59.60	0.0027
A_1	21	0.1556	0.1426	19.25	0.1595
A_2	8	0.0593	0.0756	10.21	0.4793
B	38	0.2815	0.2848	38.45	0.0053
A_1B	3	0.0222	0.0350	4.72	0.0342
A_2B	5	0.0370	0.0205	2.77	
Total	135	1.0000	0.9999	135.00	0.6810

Gene frequencies

P_1	0.0931
P_2	0.0547
q	0.1878
r	0.6644
Total	1.0000

TABLE 8

MNS groups of Yoruba

Phenotype	Number observed	Frequency observed	Frequency expected	Number expected	χ^2
MMS	7	0.0519	0.0456	6.16	0.1156
MsMs	27	0.2000	0.1687	22.78	0.7823
MNS	12	0.0889	0.0999	13.49	0.1642
MsNs	45	0.3333	0.3973	53.64	1.3920
NNS	8	0.0593	0.0545	7.36	0.0565
NsNs	36	0.2667	0.2339	31.58	0.6187
Total	135	1.0001	0.9999	135.01	3.1293

Chromosome frequencies

MS	0.0522
Ms	0.4108
NS	0.0534
Ns	0.4837
Total	1.0001

which of the MNSs chromosomes carry the Henshaw gene. They are consistent with its going only with N, but if so then in at least two out of the 5 positives it accompanied Ns, not NS as previous tests showed to be the rule in Nigeria.

The frequency of the V antigen also has proved to be very high both in Fulani (46.6%) and in Yoruba (40%). In agreement with previous findings, the V gene appears to accompany only cDe, cD^ue or cde, and mainly cDe, in these populations.

The Yoruba have been found to have a high incidence of the haptoglobin type 1-1, and a large number of individuals with very little or no haptoglobin (Allison, Blumberg and ap Rees, '58). Preliminary studies on the Fulani reveal a similar pattern. The Fulani also have a high frequency of the transferring D gene (Tf^D). (Blumberg and Gentile, '61).

SUMMARY

The blood groups of Nigerian Yoruba and Fulani have been studied. There is a suggestion of some Mediterranean admixture in the Fulani. The results in the Yoruba are consistent with previous studies.

ACKNOWLEDGMENTS

We would like to acknowledge the assistance and encouragement given to us by Professor B.G.T. Elmes, University College, Ibadan. Mr. O. Oyefesu assisted in the collection of blood specimens. A part of this work was carried out during an expedition supported by the Wenner-Gren Foundation, Inc.

TABLE 9

The Rh groups of the Yoruba

Phenotype	Number observed	Frequency observed	Frequency expected	Number expected
ccDeeV	47	0.3481	0.3439	46.43
ccDeevv	56	0.4148	0.4201	56.72
CcDeeV	4	0.0296	0.0347	4.68
CcDeevv	16	0.1185	0.0974	13.14
ccDEeV	—	—	0.0050	0.68
ccDEevv	1	0.0074	0.0151	2.05
ccD^{u}eeV	1	0.0074	0.0074	1.00
CCDeevv	—	—	0.0056	0.75
CcDEevv	—	—	0.0018	0.24
ccDEEvv	1	0.0074	0.0001	0.02
CcddeeV	1	0.0074	0.0011	0.15
Ccddeevv	1	0.0074	0.0137	1.85
CCddeevv	—	—	0.0011	0.14
CcD^{u}eeV	—	—	0.0010	0.14
ccddeeV	1	0.0074	0.0073	0.99
ccddeevv	6	0.0444	0.0446	6.02
Total	135	0.9998	0.9999	135.00

Chromosome frequencies

CDev	0.0490
cDEv	0.0111
Cdev	0.0325
cDeV	0.1933
cDev	0.4705
cD^{u}eV	0.0157
cdeV	0.0166
cdev	0.2112
Total	0.9999

TABLE 10

The P and Kell groups of the Yoruba

P_1^+	122	K+	4
P_1^-	13	K−	131

TABLE 11

The Henshaw groups of the Yoruba

MNS phenotype	He+
MNS	0
MsMs	0
MNS	1
MsNs	0
NNS	1
NsNs	1
Total	3

LITERATURE CITED

Allison, A. C., B. S. Blumberg and W. ap Rees 1958 Haptoglobin types in British, Spanish Basque and Nigerian populations. Nature, *181:* 824–825.

Barnicot, N. A., E. W. Ikin and A. E. Mourant 1954 Les groupes sanguins ABO, MNS et Rh des Touareg de l'Air. Anthropologie, *58:* 231–240.

Blumberg, B. S., and Z. Gentile 1961 The haptoglobins and transferrins of two tropical populations. Nature, *189:* 897–899.

Chalmers, J. N. M., E. W. Ikin and A. E. Mourant 1953 The ABO, MNS, and Rh blood groups of the Nigerians. Ann. Eugenics, *17:* 168–176.

Garlick, J. P. 1957 Personal communication quoted by A. E. Mourant, A. C. Kopec and K. Domaniewska-Sobczak 1958 The ABO Blood Groups: Comprehensive Tables and Maps of World Distribution. Blackwell Scientific Publications, Oxford.

Garlick, J. P., and N. A. Barnicot 1957 Blood groups and hemoglobin variants in Nigerian (Yoruba) schoolchildren. Ann. Hum. Gen., *21:* 420–425.

Greenberg, J. H. 1949 Studies in African linguistic classification. II. The classification of Fulani. Southwestern J. Anthrop., *5:* 190–198.

Jacquemin, P. 1952 Personal communication quoted by A. E. Mourant, 1954. The Distribution of the Human Blood Groups. Blackwell Scientific Publications, Oxford.

Koerber, R. 1947 Contribution à l'étude de la répartition des groupes sanguins chez quelques races de l'Afrique Occidentale Française. C. R. Soc. Biol., *141:* 1013–1015.

Koerber, R., and J. Linhard 1951 Note sur la répartition des groupes sanguins AB, A, B, et O, dans divers groupes ethniques de l'Afrique Occidentale Francaise. Bull. Soc. Anthrop., Paris, *2:* 158–160.

Kossovitch, N. 1934 Recherches Séro-Anthropologiques chez quelques peuples du Sahara Français. C. R. Biol., *116:* 759–761.

Lestrange, M. de 1949 Contribution à l'étude de l'Anthropologie des Noirs d'A.O.F.; 1) Physiologie et pathologie des Coniaqui, Bassari, Badyaranké, et Peuls de la Région de Youkounkoun (Guinée Française). Bull. Soc. Anthrop., Paris, *10:* 156–165.

Messerlin, A., and Y. Lohro 1951 Groupes sanguins et facteur rhésus au Maroc. Bull. Inst. Hyg. Maroc., n.s. *11:* 97–119.

Moullec, J., and J. Linhard 1955 2nd Congres Nat. Transfus. Sang, Bordeaux, pp. 114–118.

Mourant, A. E. 1949 Rh phenotypes and Fisher's CDE notation. Nature, *163:* 913.

Muller, H. R. 1926–1927 Blood groups among the Yoruba Tribe of West African Negroes. Proc. Soc. Exp. Biol., *24:* 437–438.

St. Croix, F. W. de 1945 The Fulani of Northern Nigeria. The Govt. Printer, Lagos, 74 pp.

Steinberg, A. G., R. Stauffer, B. S. Blumberg and H. Fudenberg 1961 Gm phenotypes and genotypes in U. S. Whites and Negroes; in American Indians and Eskimos; in Africans; and in Micronesians. Am. J. Human Gen., *13:* 205–213.

Trincão, C. 1953 Grupos sanguineos dos indigenas da Guiné Portuguesa. Prim. Coloquio Hemat. Afric., Lisbon, pp. 65–67.

Verger, P. 1955 Yoruba influences in Brazil. ODU, J. of Yoruba and related studies, *1:* 3–11.

Age, Environment and Migration: Further Anthropometric Findings on Migrant and Non-Migrant Mexicans

GABRIEL WARD LASKER AND F. GAYNOR EVANS
Department of Anatomy, Wayne State University College of Medicine, Detroit, Michigan, and Department of Anatomy, The University of Michigan School of Medicine, Ann Arbor, Michigan

The purpose of the present study is to contribute additional data for the analysis of factors influencing differences in anthropological measurements of migrant and non-migrant Mexicans. The data for the present study was collected in the Mexican community of Uruapan, State of Michoacán, Mexico in 1948. The investigation was supported by a research grant from the Wenner-Gren Foundation for Anthropological Research. Data on 477 adults, previously collected in the town of Paracho, has been used in a series of similar studies by Lasker ('52a, b, '53a, b, and '54), and by Kaplan ('53a, b).

MATERIALS AND METHODS

In the present study a series of measurements similar to those employed by Lasker, (loc. cit.) were taken by Evans on 159 adult males and 121 adult females in Uruapan. Uruapan is a city of approximately 40,000 inhabitants, located in the mountain country on the border of the Tarascan Indian zone. The people are predominantly Mestizo and lead a characteristically Mexican way of life. Although Uruapan is only 35 kilometers from Paracho, the social origins of the people measured are probably more analogous to the Mexicans studied by Goldstein ('43) and Kelly ('47) than to the people of Paracho who are somewhat more Indian.

The principle question involved in the present studies is whether there are significant differences in mean measurements of a variety of body dimensions between (a) Mexicans in Uruapan who were born and have always lived in Mexico, (b) those born there but who have lived, for various periods of time and beginning at various ages, in the United States, and (c) persons living in Uruapan who were born in the United States of Mexican parents.

The male individuals were divided into 6 subgroups and the females into 4 subgroups. The first male subgroup (1) consisted of the sedentes, or individuals who were born and had lived all their lives in Mexico. The second group of men (2) consisted of those who were born in the United States but were living in Mexico. The third group (3) consisted of individuals who were 16 years of age or less the first time they left Mexico and who were out of the country for two years or more. The fourth group (4) consisted of individuals whose ages varied between 17 and 26 years of age the first time they left the country and who also remained out of the country two or more years. The fifth group (5) consisted of men who were 26 years of age or less the first time they left the country and who remained away for one year. The final group of men (6) were 27 years or older the first time they left Mexico.

The first group of females (7) were the sedentes, the second group (8) consisted of those born in the United States but who were living in Mexico. The third group (9) were 16 years of age or less the first time they left Mexico and stayed away for two or more years. The fourth group (10) were women who were 17 or more years of age the first time they left Mexico and who also stayed away for two or more years.

The statistically significant differences between the means for the various physical characteristics measured were ana-

TABLE 1

Means and standard errors of the means of measurements of sedentes and migrant Mexicans in Uruapan, Mexico (males)

Series	1		2		3		4		5		6	
Migration	Sedentes		Born in U.S.A.		16 or less for 2 yrs. or more		17–26 for 2 yrs. or more		26 or less for 1 yr.		27 or more	
Number	55–58		10		19–22		37–39		9		20–21	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Age	30.5	1.9	21.7	0.8	40.4	2.9	46.0	1.2	33.1	4.1	45.1	2.3
Stature	1657.6	8.4	1678.5	23.8	1643.6	12.7	1638.4	9.9	1684.5	37.7	1650.2	11.7
Sitting height	868.4	4.9	862.5	10.3	864.4	7.0	853.2	5.5	859.8	9.5	860.1	6.7
Biacromial	347.5	3.4	357.0	5.3	348.6	4.2	351.1	4.8	338.7	5.7	349.4	6.5
Chest width	292.4	3.5	285.5	5.9	307.5	5.4	299.9	5.0	279.2	8.2	295.6	5.8
Chest depth	207.7	2.5	207.5	4.8	228.1	4.6	225.5	3.6	204.8	7.8	223.0	3.5
Arm length	740.5	4.7	754.5	12.2	732.2	7.8	727.7	6.8	748.9	9.6	761.2	12.7
Radius length	245.8	1.4	249.9	5.3	247.3	2.6	246.2	2.4	245.4	3.9	252.9	2.9
Tibia length	375.5	2.9	392.5	8.8	376.3	4.3	375.7	3.6	374.2	4.6	379.1	4.4
Hand length	179.8	1.1	185.1	2.9	177.9	1.9	177.7	1.6	181.8	2.5	181.4	2.2
Hand breadth	82.1	0.6	86.4	1.7	83.2	0.9	83.1	0.8	83.1	1.6	82.8	1.1
Foot length	253.0	1.4	259.9	3.1	254.5	2.8	252.6	2.0	252.3	3.5	252.2	2.5
Head length	187.5	0.8	186.6	2.8	188.6	1.4	189.3	1.2	186.4	1.5	185.6	1.2
Head breadth	149.5	0.7	149.1	1.5	151.1	0.9	148.1	0.9	148.7	1.0	147.4	1.2
Minimum frontal	108.4	0.8	108.1	2.1	109.4	1.1	108.0	1.0	110.6	1.1	106.6	1.0
Bizygomatic	136.3	0.8	136.2	1.6	139.2	0.9	137.4	0.9	136.2	0.9	135.7	1.0
Bigonial	104.6	0.7	105.0	1.5	109.3	1.1	107.6	0.9	107.4	1.6	102.8	1.2
Interocular	27.9	0.3	26.2	0.7	27.7	0.8	27.9	0.6	27.8	0.8	28.0	0.7
Total facial ht.	119.1	0.8	116.0	0.9	118.2	1.5	119.9	1.1	121.2	1.5	120.8	1.1
Upper facial ht.	67.6	0.6	67.3	0.9	66.8	1.0	67.7	0.9	69.3	1.5	67.4	0.8
Infradent.-menton	41.2	0.5	39.8	0.8	43.2	0.7	42.8	0.5	40.8	1.3	43.4	0.8
Nose height	50.1	0.5	49.5	0.9	49.3	1.0	51.0	0.7	51.4	0.9	49.9	1.0
Nose breadth	38.1	0.4	36.7	0.7	38.8	0.7	39.2	0.4	38.7	0.9	39.4	0.6
Mouth width	51.9	0.5	50.9	1.2	54.4	0.9	53.3	0.7	53.2	0.9	53.6	1.0
Ear height	64.3	0.6	61.9	1.1	66.9	0.9	66.1	0.7	65.7	1.4	65.5	1.0
Ear width	35.6	0.4	33.8	0.7	35.9	0.6	34.9	0.5	35.7	1.0	35.0	0.7

lyzed by means of Student's "t" tests in which t = the difference between the means of the two subgroups divided by the standard error of the difference. Those differences which are statistically significant at the 5% level of probability are so designated in the tables and figures.

RESULTS

Age differences

The data for the various subgroups of individuals are summarized in tables 1 and 2. Figures 2 through 26 show that there are 80 statistically significant differences between mean measurements of subgroups of the same sex.

A closer examination of the statistically significant differences among the various physical characteristics reveals that many of them are what one would expect on the basis of the mean age differences between the various subgroups (fig. 1). Age differences in measurements have been noted by other investigators (table 3); age changes apparently account for most of these differences but only a few investigators report data on the same individuals measured on different occasions.

From the data presented in table 3 it is evident that stature decreases with age. This can account for the fact that the subgroup of females of the youngest average age, i.e., the American-born (8), are significantly taller than the two oldest subgroups (7 and 10). Sitting height also seems to decrease with age, which explains a significant difference between the stature of the same subgroups. Age may also account for the fact that the male subgroup with the oldest mean age (4) is significantly shorter than the subgroup with the youngest mean age, the American-born (2).

TABLE 2

Means and standard errors of the means of the measurements of sedentes and migrant Mexicans in Uruapan, Mexico (females)

Series	7		8		9		10	
Migration	Sedentes		Born in U.S.A.		16 or less for 2 yrs. or more		17 or more for 2 yrs. or more	
Number	67–70		15–16		18–20		13–15	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Age	36.07	1.7	21.31	2.5	33.60	1.5	50.00	2.0
Stature	1522.1	7.2	1553.3	12.9	1525.0	10.5	1489.8	17.3
Sitting height	796.9	4.8	815.3	6.0	803.1	7.9	781.3	10.4
Biacromial	311.7	2.7	305.1	7.2	310.0	4.5	315.7	6.9
Chest width	215.3	3.0	267.3	6.7	272.0	5.1	281.7	7.3
Arm length	678.1	3.8	678.5	7.4	667.0	6.8	662.5	6.8
Radius length	226.2	1.6	223.9	3.2	223.1	2.8	220.9	3.8
Tibia length	348.0	2.3	347.3	4.1	347.3	4.6	335.6	4.3
Hand length	164.4	0.9	168.3	1.4	164.8	1.7	163.4	2.6
Hand breadth	73.6	0.5	74.1	1.1	73.7	0.9	73.5	1.0
Foot length	229.8	1.3	236.4	2.3	228.0	2.1	228.5	3.2
Head length	179.2	0.7	178.5	1.5	180.2	1.0	177.3	1.6
Head breadth	143.6	0.6	146.3	1.5	143.7	1.2	142.5	1.2
Minimum frontal	106.1	0.7	105.9	1.3	104.9	1.1	105.6	1.3
Bizygomatic	129.4	0.7	131.5	1.5	128.2	0.9	131.7	1.2
Bigonial	100.4	0.7	102.8	1.7	98.2	0.9	100.9	1.5
Interocular	27.3	0.3	26.4	0.7	26.8	0.6	28.3	0.7
Total facial ht.	111.0	0.9	109.0	1.8	111.4	1.3	110.7	1.2
Upper facial ht.	62.4	0.5	61.6	1.7	64.0	1.2	62.1	1.5
Infradent.-menton	38.4	0.4	37.7	0.6	39.3	0.6	39.3	0.5
Nose height	45.8	0.4	46.8	1.1	47.2	0.8	46.6	0.9
Nose breadth	34.1	0.4	34.1	0.8	34.2	0.5	35.9	0.7
Mouth width	49.7	0.4	49.3	0.9	50.2	0.8	51.2	1.2
Ear height	61.1	0.5	59.5	1.2	60.6	0.6	63.6	1.1
Ear width	32.7	0.4	32.4	0.7	32.7	0.6	35.1	0.8

Several studies indicate that biacromial diameter decreases with age. The male subgroup with the youngest mean age (2) is significantly larger in this dimension than one of the older subgroups (5).

Chest width and especially chest depth increase with age. Four significant differences in chest width and 9 in chest depth all show that subgroups with older average ages are larger in these respects than those groups with younger average ages.

Little is known about age differences in the lengths of the upper limb, radius, tibia and foot.

Head length, head breadth (except in Japanese), minimum frontal, bizygomatic and bigonial breadths seem to increase with age. This, however, is not consistently reflected in the significant differences found in the present material.

Most studies, except for that of Goldstein ('36) on young and elderly Jews, indicate increases in facial heights during adulthood. Four significant differences in nasion-menton (morphological face height) and 8 of infradentale-menton (lower face height) show the youngest and next to the youngest subgroups significantly smaller in these respects than other subgroups of greater average age.

Nose breadth and mouth width increase progressively with age which may account for the significant differences in these features.

Age changes in interocular breadth are unknown.

Hand length and breadth may increase with age. However, the significant differences in hand dimensions between subgroups are not those one would expect on the basis of age.

Both ear dimensions increase with age. The 9 significant differences in ear height and 4 in ear breadth show that the subgroups of greater average age are larger in these respects.

Remaining differences

There are 30 differences at the 5% level of significance which pertain to the following measurements: first, those having no definite age trend, or those in which the observed differences are not explicable on the basis of the age, and second, those differences pertaining to a dimension where some other significant comparison is contrary to the age expectation. Thirty differences represent only 5.85% of the 513 subgroup comparisons tested for significance.

Although the remaining 30 significant differences may well be random, two possible ways of explaining some of them are: first, a tendency toward a selective factor differentiating sedentes from migrants, including those who first went to the United States as adults; second, the effects of environmental differences between Mexico and the United States. The latter factor would be manifested by a measurement gradient varying from the sedentes through migrants who spent short periods in the United States to those who spent most of their growth period there.

Males who went to the United States when fully mature (6) have a significantly longer upper limb than those who migrated before the age of 16. The radius length of

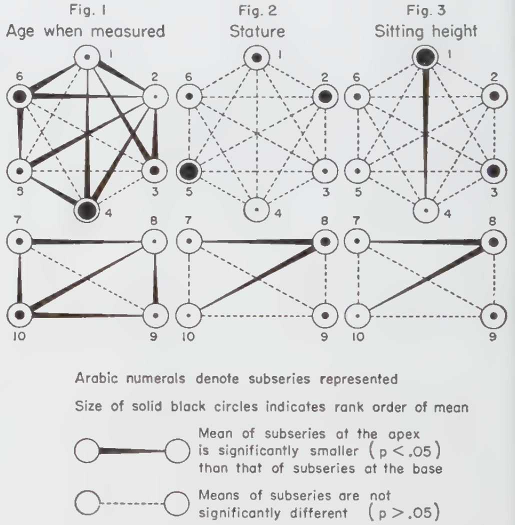


Fig. 1
Age when measured
Fig. 2
Stature
Fig. 3
Sitting height
1
2
3
4
5
6
7
8
9
10
Arabic numerals denote subseries represented
Size of solid black circles indicates rank order of mean
Mean of subseries at the apex is significantly smaller ($p < .05$) than that of subseries at the base
Means of subseries are not significantly different ($p > .05$)

Figs. 1–26 A comparison of age and measurements between different subgroups of Mexicans in Uruapan. *Males:* 1, sedentes; 2, born in the United States of America; 3, first migrated at age of 16 or less and stayed for two or more years; 4, first migrated between 17 and 26 years of age and remained for two or more years; 5, first migrated at 26 years of age or younger and remained for one year; 6, first migrated at 27 years of age or older.

Females: 7, sedentes; 8, born in the United States of America; 9, first migrated at age of 16 or less and stayed for two or more years; 10, first migrated at 17 years of age or older and stayed for two years or more.

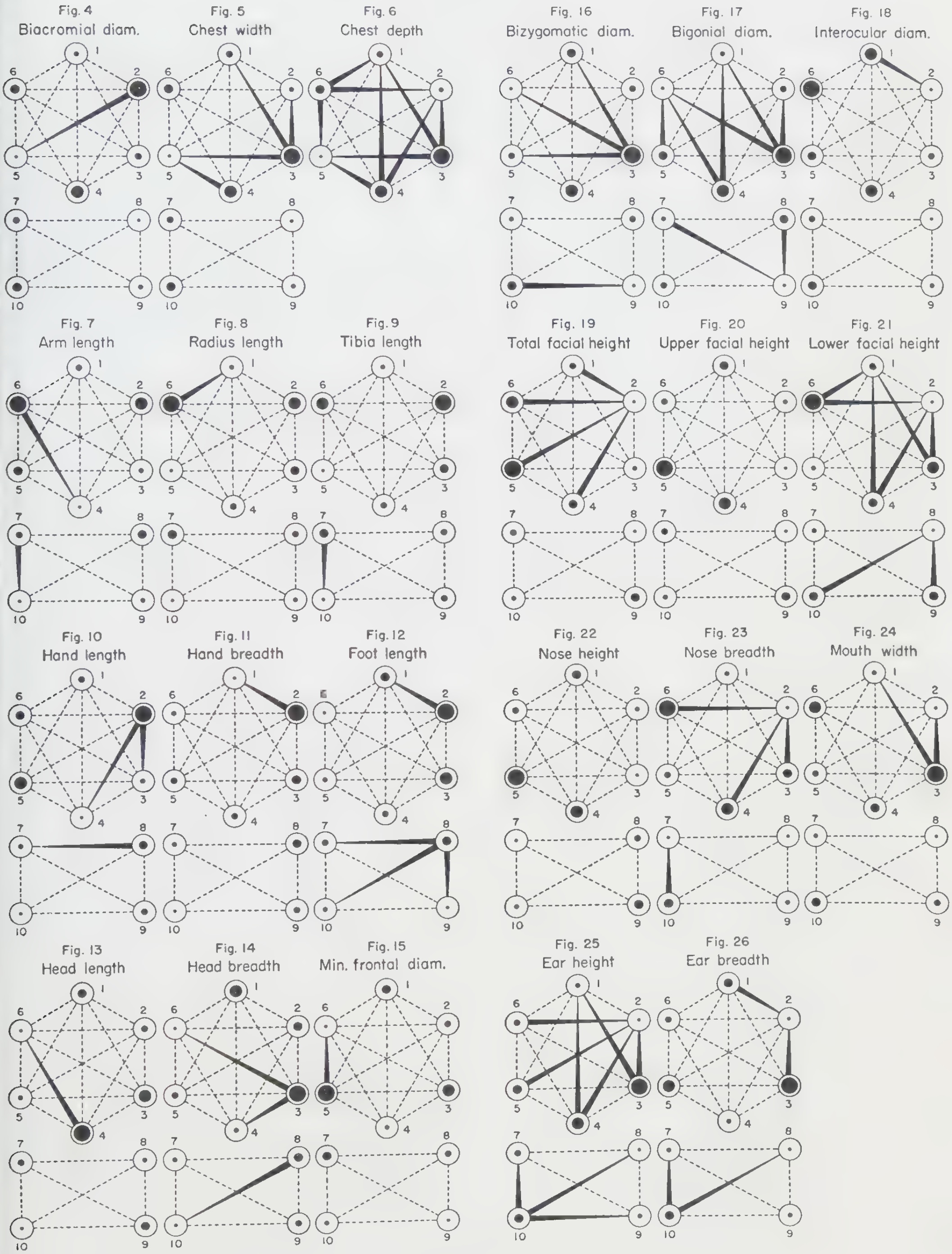


Fig. 4 Biacromial diam.

Fig. 5 Chest width

Fig. 6 Chest depth

Fig. 7 Arm length

Fig. 8 Radius length

Fig. 9 Tibia length

Fig. 10 Hand length

Fig. 11 Hand breadth

Fig. 12 Foot length

Fig. 13 Head length

Fig. 14 Head breadth

Fig. 15 Min. frontal diam.

Fig. 16 Bizygomatic diam.

Fig. 17 Bigonial diam.

Fig. 18 Interocular diam.

Fig. 19 Total facial height

Fig. 20 Upper facial height

Fig. 21 Lower facial height

Fig. 22 Nose height

Fig. 23 Nose breadth

Fig. 24 Mouth width

Fig. 25 Ear height

Fig. 26 Ear breadth

Figures 4 to 26

TABLE 3

Age differences in adults from published sources

	Increases with age		Decreases with age		None, other or irregular trends	
	Male	Female	Male	Female	Male	Female
Stature			1,4,5,7,9,10,11,14	4,6,9,11,14		10
Sitting height			7,10	10	4,5	4
Biacromial			7,9	9	5,10	6,10
Chest width	5,14	10,14			10	
Chest depth	5,10,14	14				
Arm length					7,10	6,10
Radial length					10	10
Tibia length			10			10
Foot length					10	10
Head length	1,4,5,7,8,9,12	4,6,8,10,12	2		10,11,15	9,11
Head breadth	4,5	4,10,11	7,8,9,12	8,9,12	1,2,10,11,15	6
Minimum frontal	2,4	4	1		5,10,11	10,11
Bizygomatic	2,4,5,10,11,15	4,10,11			1,7,9	6,9,10
Bigonial	2,4,5,10,11	4,10			7,9	6,9,11
Total morphological face height	1,4,7,11,15	4,6,10,15	2		5,9,10	9,11
Upper face height	4,5	4	2		10	10
Lower face height	15	10	2		10	
Nose height	1,2,5,7,9,11,15	6,9			10	10,11
Nose breadth	1,2,5,7,9,10,11	6,9,10,11				
Mouth width	2,9,10	9,10				
Interocular					10	10
Hand length	3	3			10,11	10,11
Hand breadth	3	3,11			10,11	10
Ear height	7,10,11,13	6,10,11,13	12	12		
Ear breadth	7,10,11,13	6,10,11,13				

(1) Hawaiians (Wissler, '27); (2) American Jews (Goldstein, '36); (3) Swiss (Büchi, '49); (4) Swiss (Büchi, '50); (5) Irish (Hooton and Dupertuis, '51); (6) Japanese (Ikeda and Yasuzawa, '51); (7) Japanese (Yasuzawa, '51); (8) Japanese (Kakimoto, '53); (9) Japanese (Otsuki, '53); (10) Mexicans (Lasker, '53); (11) Mexicans (Goldstein—see Lasker, '53); (12) Japanese (Yoshihisa et al., '54); (13) Japanese (Tubaki and Onuki, '55); (14) Japanese (Takahashi and Atsumi, '55); (15) Americans (Baer, '56).

those who migrated when mature (6) is also longer than that of sedentes (1). These findings would be consistent with the *a priori* assumption of selection for long arms in mature worker migrants. However, no such difference was found in Paracho (Lasker, '52). The fact that sedente females (7) have significantly longer arms than one subgroup of female migrants (10) does not obviate the possibility of selection limited to males. The tibial length of female sedentes is significantly longer than that of the same group of migrants (10). This corresponds to the findings for the upper extremity.

In hand length the United States-born males exceed two of the migrant sugroups (3 and 4) and the United States-born females exceed the sedentes. In hand breadth the United States-born males exceed the sedentes and in foot length the United States-born males exceed the sedentes and the United States-born females exceed every other female subgroup. These differences are the clearest evidence of an environmental factor.

The possibility of a selective migration from Mexico specifically involving hand breadth has been discussed previously (Lasker, '54). The present findings suggest that Mexicans living in the United States may have larger hands and feet than those living in Mexico, a conclusion consistent with the results of previous studies by Goldstein ('43) and Lasker ('52b). Similar reasons may account for the fact that most Americans living abroad find that shoes available for purchase are too small for them.

The head length of mature male migrants who went to the United States (6) is significantly smaller than that of one other group of migrants (4). The head breadth of male migrants who went when young (3) is significantly greater than that of two other groups of migrants (4 and 6). In females the head breadth of the United States-born is significantly greater than that of one of the migrant groups (10). The data for head breadth suggests that the migrants who first went to the United States when young and the United States-born may tend to have wider heads because of an environmental effect during growth. This corresponds in general with the finding in Paracho (Lasker, '52b) and with that of Shapiro ('39) on Japanese but not with Goldstein's ('43) data on Mexicans born in the United States.

In minimum frontal diameter one group of migrants (5) is significantly different from another (6) but there is no ready explanation.

In bizygomatic diameter the males of subgroup 3 significantly exceed sedentes and two of the other subgroups of migrants (5 and 6). This is in general accord with the previous findings on Mexicans (Goldstein, '43; Lasker, '52b) and would suggest the environmental factor were it not for Goldstein's observation of narrower faces in a large group of United States-born Mexicans. Furthermore, the fact that the bizygomatic diameter in females of subgroup 10 is significantly greater than that of subgroup 9 does not add weight to the argument.

The bigonial diameter shows a whole series of significant differences. Among males, the younger the migrants were when they went to the United States and the longer they stayed the larger this measurement. The male migrants who went when 27 or more years of age and the sedentes are the smallest in this dimension. These facts strongly suggest an environmental factor. However, the American-born group is also significantly smaller in bigonial diameter than one group of migrants (3). The findings on bigonial diameter accord with previous data on Mexicans (Goldstein, '43; Lasker, '52b). If one adds the postulate of the age factor it helps to account for the small bigonial diameter in sedentes and American-born males. Otherwise, it is difficult to explain the female data in which both sedentes and United States-born subgroups have significantly larger bigonial diameters than women who migrated to the United States before the age of 17 (9).

Male sedentes exceed American-born in interocular width. In other breadth measurements it is the migrants who tend to exceed the sedentes.

Because of a suggestion of an environmental factor in some measurements, the differences in stature, sitting height, and biacromial diameter may be explained on the basis of environment as well as of age. Differences in these measurements are also consistent with the hypothesis of the environmental factor in previous studies (Shapiro, '39; Goldstein, '43; Lasker, '52; Kaplan, '54).

SUMMARY

1. A series of anthropometric measurements were taken on 159 adult male and 121 adult female individuals living in the town of Uruapan, State of Michoacán, Mexico.

2. The problem studied was whether or not there are significant differences in the mean measurements for the various body dimensions between (a) individuals who were born in Mexico and have always lived there, (b) individuals born in Mexico but who have lived, for various periods of time and beginning at different ages, in the United States, and (c) individuals living

in Uruapan who were born in the United States of Mexican parents.

3. To facilitate the study the male individuals were classified into 6 subgroups and the females into 4 subgroups. The basis of classification into subgroups was (a) the country of birth, (b) whether or not the individuals had ever left Mexico, and (c) the age at leaving Mexico and the length of time spent outside of Mexico.

4. The statistical significance of differences between the means for the various anthropometric measurements were analyzed by means of Student's "t" tests. The differences which were statistically significant at the 5% level of probability were indicated in the tables and figures.

5. Eighty statistically significant differences between mean measurements of subgroups of the same sex were found. Many of these differences are explainable on the basis of the mean age differences between the various subgroups.

6. Thirty additional differences at the 5% level of significance were also found. These differences pertained to measurements which (a) have no definite age trend or which are unexplainable on the basis of age or (b) differences where some other significant comparison is contrary to the age expectation. These 30 differences represent only 5.85% of the 513 subgroup comparisons tested for significance.

7. An environmental factor as well as age may account for some of the significant differences found in the study.

CONCLUSIONS

The difficulty of categorizing the various factors responsible for adult anthropometric dimensions is apparent from this study of Mexicans in Uruapan. The extreme importance of adult age changes is emphasized by the fact that most of the significant differences between subgroups of the same sex are consistent with and could very well result from differences in average age.

In an anthropometric study, small differences in the means are likely to be significant, and the investigator should consider the age of the subjects. This can be done only in a crude way in this study because in order to account for age differences, considerable data which might have a bearing on selective migration as well as environmental effects must be eliminated. In some instances it may be desirable to match series for age at the time of collection of the data.

Although a larger series for the study of such subtle factors as selection and environmental effects would be desirable, certain tendencies are evident from the present study. There is a suggestion that broader heads and faces (maximum head breadth, bizygomatic diameter, bigonial diameter) in the United States may be the result of an environmental factor. This suggestion is even more tenuous in respect to hand length, hand breadth and foot length. It may also be involved in the observed differences in stature, sitting height and biacromial diameter.

The only evidence in the present study of a physical selection of migrants who returned home is a tendency toward longer upper limbs in male migrants who were fully mature when they first went to the United States.

ACKNOWLEDGMENTS

The authors wish to express their indebtedness to Señora Beatrice del Castillo and Mrs. F. Gaynor Evans for their invaluable assistance in the collection of the data upon which the present study is based. Without the services of Señora del Castillo as an interpreter the subjects could not have been interviewed and measured.

LITERATURE CITED

Baer, M. J. 1956 Dimensional changes in the human head and face in the third decade of life. Am. J. Phys. Anthrop., n.s. *14:* 557–576.

Büchi, E. C. 1949 Beobachtung über das Verhalten der Handform im postjuvenilen Alter. Arch. der Julius Klaus-Stiftung, *24:* 248–262.

——— 1950 Änderungen der Körperform beim erwachsamen Menschen. Anthropologische Forschungen von der Anthropologische Gesellschaft in Wien, *1:* 1–44.

Goldstein, M. S. 1936 Changes in dimensions and form of the face and head with age. Am. J. Phys. Anthrop., *22:* 37–89.

——— 1943 Demographic and Bodily Changes in Descendants of Mexican Immigrants with Comparable Data on Parents and Children in Mexico. Publication of the Institute of Latin-American Studies, University of Texas, Austin, Texas.

Hooton, E. A., and C. W. Dupertuis 1951 Age changes and selective survival in Irish Males. Studies in Physical Anthropology, no. 2. Am. Assoc. Phys. Anthrop. and the Wenner-Gren Foundation.

Ikeda, Z., and K. Yasuzawa 1951 A physical-anthropological investigation on the female natives of the Seto Inland Sea. Anthropological Reports, Dept. of Anatomy, Hiroshima Medical College, Kure, Japan, no. 6.

Kakimoto, K. 1953 The degree of changes in headlength, headbreadth and cephalic index with age. Ibid., no. 7, 42–58.

Kaplan, B. A. 1953a Ethnic identification in an Indian Mestizo community. I. Socio-cultural factors. Phylon, Atlanta University Review of Race and Culture, *14:* 179–186.

——— 1953b Social and Technological Change. Paracho: a Case in Point. Ph.D. dissertation, University of Chicago. Typescript.

——— 1954 Environment and human plasticity. American Anthropologist, *56:* 780–800.

Kelly, A. R. 1947 Physical Anthropology of a Mexican Population in Texas: A Study in Race Mixture. Middle American Research Institute, Tulane University, New Orleans, Louisiana, Publication no. 13.

Lasker, G. W. 1952a An anthropometric study of returned Mexican emigrants. Tax: Indiana Tribes of Aboriginal America, Proceedings of the 29th Congress of Americanists, *3:* 242–246. University of Chicago Press, Chicago.

——— 1952b Environmental growth factors and selective migration. Human Biology, *24:* 262–289.

——— 1953a The age factor in bodily measurements of adult male and female Mexicans. Ibid., *25:* 50–63.

——— 1953b Ethnic identification in an Indian Mestizo community. II. Racial characteristics. Phylon, Atlanta University Review of Race and Culture, *14:* 187–190.

——— 1954 The question of physical selection of Mexican migrants to the United States of America. Human Biology, *26:* 52–58.

Otsuki, K. 1953 Anthropometry on the Japanese old. Anthropological Reports, Dept. of Anatomy, Hiroshima Medical College, Kure, Japan, Special no. 5.

Shapiro, H. L. 1939 Migration and Environment. Oxford University Press, New York.

Tubaki, K., and H. Onuki 1955 On changes of the ear size with age, especially in its physiognomic length and breadth. Quart. J. Anthrop., Dept. of Anatomy, Kyushu University, Fukuoka, Japan, *2:* 245–256.

Wissler, C. 1927 Age changes in anthropological characters in childhood and adult life. Proc. Am. Philosophical Soc., *66:* 431–438.

Yasuzawa, K. 1951 Physical-anthropological investigation of the male Japanese prisoners. Anthropological Reports, Department of Anatomy, Hiroshima Medical College, Kure, Japan, Special no. 1.

Yoshihisa, K., C. Sento and K. Takahashi 1954 Changes in dimension of the ear with age. Anthropological Reports, Dept. of Anatomy, Niigata Univ. School of Medicine, Niigata, Japan, no. 9, 11–20.

Book Reviews

GENETIC BASIS OF MORPHOLOGICAL VARIATION by R. H. Osborne and F. V. De George xxii + 204 pp., $5.00. Harvard University Press, Cambridge 1959.

Most of normal human variation is quantitative, a fact which is now becoming evident even from blood group studies, and one of the central problems in anthropology today is to find ways of analyzing this variation in terms of the precise nature of its genetically determined component and in terms of the magnitude and biological significance of the contribution so frequently made by environmental heterogeneity.

The "Genetic Basis of Morphological Variation" makes a fundamental contribution to the understanding of this problem. The approach is through twin studies and the book is largely concerned with a particular investigation carried out by the authors on over a 100 adult twin pairs in New York, about half of which were monozygotic. However, it is not merely a report of the results of this investigation, but also a complete appraisal of the value and methods of twin research and is full of stimulating and original ideas. Particularly important, in view of the strong criticisms that have recently been directed at twin studies, is the discussion of the apparent discrepancies between heritability estimates obtained from twin data and those obtained from other sources. In explanation the authors rightly emphasize the ramifying effects of the complete identity of genotype which characterizes monozygotic twins but they seem to neglect that one of the consequences of having exactly the same homeostatic mechanisms is that the responses of such twins to environmental variation will tend to be more uniform than those of dizygotic twins. Mongolism is rather a special case where incompatible heritability estimates have been found. When the book was written the causes of this abnormality were not known, but the authors point out that, although the concordance in monozygotic twins is high and other types of analysis indicate only slight genetic determination, the validity of the twin estimates need not be doubted if cognizance is taken of the unique genetic makeup of the twins. Now that it is known that mongolism is due to trisomy the fact that the estimates are different is completely explicable and each is meaningful. One is only left wondering why concordance in monozygotic twins is not apparently complete. One of the most likely explanations is that the cases of non-concordance are due to errors in zygosity diagnosis. The problem of distinguishing between monozygotic and dizygotic twins is considered in great detail in the book and it is apparent from rigorous procedure which the authors employed, that faulty diagnosis is unlikely to be a source of error in their own study.

In the general review of twin methods the pitfalls to be avoided in obtaining a twin sample are comprehensively considered. In particular, much attention is given to the problems of ascertainment and the bias that can be introduced by uncritical application of Weinberg's differential method for calculating the expected number of dizygotic and monozygotic twins in a population. In this connection it may be pointed out that, contrary to statements made in the book, the likelihood of having monozygotic twins increases with maternal age, but this does not invalidate the author's appraisal of the possible consequence of maternal age effects on twinning rate. The principal factor, of course, that upsets Weinberg expectations is differential mortality of like and unlike sexed twins.

So far as the particular study is concerned, the main object was to determine whether a hereditary component to normal morphological variability can be measured by the twin method with the techniques at present available. The approach was to compare by F-tests, the magnitude of intra-pair variances, of monozygotic and dizygotic twins in many anthropometric and other morphological characters such as fat, bone and muscle development and somatotyping and masculinity-femininity ratings. In addition, comparisons were made between intra-pair and inter-pair differences of dizygotic twins and of intra-pair monozygotic differences, with estimates of the technical error obtained by measuring the same individual twice. The effects of sex on these differences were also systematically studied, and a cross-twin analysis was employed to indicate the extent and nature of independent variation between pairs of characters, particularly those such as height and weight, head-length and head-breadth which have frequently been used for the calculation of indices of shape. The value of intra- inter-pair dizygotic twin comparisons is not particularly evident except as a general measure of the relative size of family and population heterogeneity. The authors hold that this comparison helps the interpretation of the monozygotic-dizygotic intra-pair ratios but this is only so if it can be assumed that the differential environmental effect can be neglected.

While the relative magnitude of some of the variance ratios may suggest intriguing possibilities so many different situations can lead to the same unresolveable result, that the authors have rightly refrained from making the comparisons. It needs to be said, however, that they also leave the reader to interpret many of the actual analyses made. Further, while it must be admitted that some facts are not easily explained, in places the account is unnecessarily obscure and diffuse and on occasion the arguments are definitely ambiguous. At one point, for instance, it is possible to believe the authors conclude that the greater number of genetic factors responsible for a phenotypic difference, the larger will be the population variance. In fact, of course, the situation is contrariwise. As an example of obscurity; it is suggested from the fact that the taller of a pair of monozygotic twins is as frequently the lighter as the heavier that there "may be a hereditary component for gross size involving some proportionality of height and weight that is not described by ponderal index." Let it be said, however, that commanding evidence is subsequently obtained for the view that the ponderal index is an ineffective measure of genetic variability. The difficult problem of abstracting morphological characters is throughout the study given much attention. The crucial criterion for analyses of the inheritance of quantitative variation is that on the scale employed the responsible genes are additive in effect. There is obviously not an a priori complication in dealing with characters which are produced by more than one set of genetic factors. For instance, in the unlikely event of it being found that the genes responsible for leg, trunk and head height are completely different, it would still be both possible and meaningful, though more difficult, to analyze directly the inheritance of stature. Similarly it does not necessarily matter if some abstracted character involves parts of different gene sets though this is likely to introduce the complications of genes with unequal effects, the peculiar consequences of which, on frequency distributions, seem incidentally never to have been systematically considered. On the other hand, it is apparent that if there is no particular genetic basis to a character, differences in it are resistant to genetic analysis since the most diverse genotypes possible can produce the same phenotype. This could well be the case in shape indices and while it is interesting that of all the characters studied the cephalic index was shown to display the greatest proportional difference between intra-pair monozygotic and intra-pair dizygotic variances, this does not necessarily mean that the inheritance of the character can be directly analyzed in formal terms. The strong genetic determination of the cephalic index occurs despite the fact that head length has little measurable variability of genetic origin in twins. Indeed, the male intra-pair monozygotic variance of head length, as also of ankle breadth, is actually larger than the corresponding intra-pair dizygotic variance and, though this is not statistically significant, it is suggested that some peculiar environment factor influences the character in monozygotic males. It is perhaps relevant that, as the authors point out, both ankle breadth and head length are almost entirely osseous measurements.

The general anthropometric findings of the study are that genetically determined length and breadth dimensions are relatively independent and that, excepting the head, the greatest component of genetic variability is expressed in measurements taken parallel to the long axis of the body. Of the 77 anthropometric characters considered, those which show in both sexes the relatively greatest genetically determined variation are fore-arm length, upper facial height, nose height, head height and bigonial breadth; but many others have a measurable genetic component, particularly in females who, as is to be expected, seem to possess a greater homeostatic ability. This, however, is apparently not an invariable situation. The study also confirms that in contrast with stature adult weight variation in dizygotic twins could be explained solely in terms of environmental heterogeneity. On the other hand it is established for the first time that a significant genetic component of variability exists in birth weight and also in measurements of fat, bone, muscle and in certain overall estimates of somatotype. The cross-twin analysis particularly shows that "whatever the influences may be that affect the relations between two measurements in a monozygotic twin, these influences have a similar effect between the two members of a twin pair."

It may well be asked whether the results of studies of this type are of immediate value to those anthropologists who wish to use anthropometry for determining the relationships between populations. All approaches to this problem are fraught with pitfalls, but the special limiter of anthropometric data is the unknown relationship between genotype and phenotype which is obscured even more if there is a possible environmental contribution to the variation. Although there is a relationship between the magnitude of genetically determined intra-pair dizygotic twin differences and the variation of unrelated individuals in the same population, there is obviously no connection at all between intra- and inter-population differences. More troublesome still, is the absolute independence of the environmental heterogeneity affecting families and populations. Even the study of monozygotic twins reared apart, by far the best way of estimating environmental effects, gives but a minimum value to the possible contribution that a particular environmental difference is making. And the effects of environmental variation depend not only on the magnitude of this variation, but also on the nature of its range. The most that can be said is that if a genetic component of variability can be detected in dizygotic twins, it will be contributing even more to within and between population differences. However, though the prospect remains bleak only continued research, of the sort undertaken by Osborne and De George, into the fundamental problems of quantitative morphological variation, will ever make possible the confident employment of anthropometric techniques to historical problems.

GEOFFERY A. HARRISON
University of Liverpool

THE PROCESSES OF ONGOING HUMAN EVOLUTION. Gabriel Ward Lasker, editor. 108 pp., $3.75. Wayne State University Press, Detroit 2, Michigan, 1960.

NATURAL SELECTION IN HUMAN POPULATIONS. D. F. Roberts and G. A. Harrison, editors. viii + 76 pp., $3.00. Pergamon Press Inc., New York 22, N. Y., 1959.

These two slim volumes have much in common. They both derive from professional symposia whose avowed themes echo the stimulus of the past Darwin centennial seasons; they are by and large concerned with human evolution at the processual rather than historical level; and they represent a mixture of semitechnical and frankly survey articles. If one were to venture to generalize on differences in orientation of American students of human evolution (The Processes of Ongoing Human Evolution) and British students (Natural Selection in Human Populations) one would be struck by the more anthropological and ecological concern of the former versus the more clinical and theoretical bent of the latter. The mutual concern with the population as the unit of evolution is the unifying factor and a summary of the contents of the two books is virtually a summary of the status of present research in human microevolution.

It is not possible in the space of this review to analyze the 12 varied articles which comprise these two books, and a comment or two on a few of the papers will have to suffice. In the Lasker volume the first article by Paul T. Baker ("Climate, culture, and evolution") is a brief resumé of our knowledge of the correlation of surface area/body weight relationships and climatic zones in the light of possible cultural modifications in the direction and force of selective pressures. This is a particularly stimulating attack on the problem and demonstrates clearly how the physical anthropologist *qua* anthropologist has a significant contribution to make to the study of racial variation. In citing the case of the desert-dwelling Maricopa preference for plump female mates (p. 11), Baker notes that this may be a case of sexual selection overriding climatic selection. In addition to Baker's suggestion one might speculate on the possibility that this is a biological and cultural lag from a previous condition of cold adaptation. Baker also mentions the peculiar adaptation of the Australian to nocturnal cold stress (vasoconstriction, hypothermality of the extremities, p. 4). Besides the cutural factor involved (technological poverty) it would be interesting to examine the relevance of the fact that these same aborigines must fact great diurnal heat stresses and that this may have determined the particular cold adaptation observed. One further comment which this article stimulated in the reviewer concerns the common inference that the tropical microclimate created by special clothing has diminished selection for cold-adapted SA/W types (Baker points out that this did not solve the problem of the extremities). The question is, how effective are minimal or extreme cold conditions (water immersion, exhaustion, prolonged cold exposure, low nutritional status, etc.) in the differential mortality picture of arctic peoples? Accurate, quantified studies of the distribution of causes of incapacitation and death in societies under extreme regimes might shed some light on this and other modes of selection.

Frank B. Livingstone's paper ("Natural selection, disease, and ongoing human evolution, as illustrated by the ABO blood groups") is an ingenious essay in the "indirect" method of ascertaining selection pressures at the ABO locus. Using West African data he constructs a steady state model in which drift is opposed to selection, gene flow, and mutation to maintain the observed somewhat leptokurtic distributions of the A and B frequencies. By neglecting mutation pressure and correcting for gene flow he derives some fitness values for the various ABO genotypes. The type of assumptions required makes the model a little creaky but does not reduce its heuristic value. Livingstone rightly indicates that more work is needed on detailed population analyses to yield direct estimates of effective breeding size and gene flow. His own value of gene flow (0.01) seems too low and may be partly a result of deriving it from an effective size of 1000 (island model), which appears quite high.

The final paper, "Irradiation and human evolution," by Earle Reynolds, is a survey of the sources of ionizing radiation which can affect man, with emphasis on the increased hazards of the atomic age. In it we see the emergent role of the scientist as a conscientious casuist, a role forced upon us by the patent perjury of conscience practiced by some of our scientific and quasi-scientific colleagues. It is not possible to comment on the article in the same vein as the others—it is sufficient to urge its reading.

Other papers in this collection include "Metabolic polymorphisms and the role of infectious diseases in human evolution" by Arno G. Motulsky, "Adaptation, selection, and plasticity in ongoing human evolution" by F. S. Hulse, and "Migration, isolation, and ongoing human evolution" by G. W. Lasker.

In the Roberts and Harrison volume the lead article by L. S. Penrose ("Natural selection in man: some basic problems") gives a brief, clear exposition of the present approach to human genetic problems with emphasis upon the problem of polymorphisms. In passing, the author gives a terse reminder to the biological "dead-enders": "The belief that natural selection in man has been abolished by civilization, socialism, hygiene or whatever it may be, depends on superficial reasoning. What has happened is that the force has been altered and transferred at certain points from one genotype to another" (p. 8–9). Following this article are offerings by A. R. G. Owen ("Mathematical models for selection"), C. A. Clarke (The relative fitness of human mutant genotypes"), P. M. Sheppard ("Natural selection and some polymorphic characters in man"), and T. Dobzhansky ("On selection of gene systems in natural populations").

The final article by E. H. Ashton ("Rate of change in primate evolution") catalogs our ignorance of the rate of primate evolution in the Cenozoic and discusses an effort by the author (and S. Zuckerman) to assess the speed of change in an expatriate colony of green monkeys (*Cercopithecus aethiops sabaeus*) on St. Kitts in the West Indies. Comparison with the parent populations in Africa gives high rates of morphological modification over an estimated span of 300 years. Arguing from contemporary materials, however, seems premature since no indication is given as to how much of the observed changes in such a colony may derive from "founder population" effects (errors in sampling of small migrant colonies) and not from selection or plasticity over a three century span.

The value of these books lies principally in the succint overview they provide of many areas of the problem of human microevolution. The bibliographies at the end of each essay are generally extensive. The only difficulty noted was in the matter of style. Having attended the December 1959 meetings of the American Anthropological Association in Mexico City where the Lasker symposium was given, it was possible for the reviewer to compare the impact of the verbal and written deliveries. It was noted that those papers which were successful in oral transmission often appear too rhetorical and repetitious in print, while papers of a tightly reasoned and stimulating aspect in print were almost totally incomprehensible when delivered at the symposium. The suitability of transferring a given essay from one medium to the other without reworking may, as a result, frequently be questionable.

Robert A. Littlewood
Washington State University

NATURE AND MAN'S FATE. By Garrett Hardin. xi + 349 pp. + bibliography 11 pp.; 8 plates, 25 figures. Rinehart & Company, Inc., New York. 1959. $6.00.

This is non-technical account of evolutionary theory and heredity with some notable exceptions. Opening with a concise description of the heart of the dilemma posed by Charles Darwin 100 years ago, the author proceeds admirably to rid himself first of one horn and then the other. The Principle of Competitive Exclusion, not explicitly formulated by Darwin, is here concisely defined, or at least as clearly stated as our present knowledge permits. He discusses the political atmosphere of our times and the acceptance or rejection of the scientist's concept of pure evolution by "the people." He opens with an admirable description in good prose of the times before Darwin's and Wallace's opus struck the unsuspecting and unwilling public and then proceeds in equally readable form to tell the story well. He makes Darwin quite human. The titles of his chapters are original jargon but they draw the reader's interest. The meat of the book is written in an interesting style.

In the first few chapters he is at his best. The line drawings are somewhat over simplified and will be less appreciated by his scientifically minded lay readers and unnecessary for the scientist. The aesthetic and emotional reactions section is well done. Heredity and genetics are concisely and pleasantly defined for the lay reader as are his biologic explanations in general. The philosophy and rationale of it all are vividly written, with no let up to the end. It is a book that the professional and the lay reader will enjoy. As entertaining reading that is equally informative it should serve well for introductory classes in any undergraduate institution. All physicians should read it. It is provocative and lively and the portraits are excellent as well as the index. The paper is not glaring and the print is clear.

C. W. Goff
30 Farmington Ave.
Hartford, Conn.

BEHAVIOR AND EVOLUTION. By Anne Roe and George G. Simpson, eds. vii + 557 pp. Yale University Press, New Haven, 1958.

This is a multidimensional approach to processes of change in biology (somatic and neural structure, physiology, and their ecological interrelations) and in action (behavior patterns, learning, ethology, social relations, and, finally, culture). In the past, students of evolution always mentioned behavior as part of their data but did not study it analyically and psychologists did not analyze the evolutionary background of any group, bird, ant, fruit-fly, or human, when they studied its behavior. Points of cross-sighting between these two types of discipline and between the intra-individual (e.g., genetic, endocrine, neurological) and the extra-individual (e.g., sociological, demographic) data on adaptation of changing populations to changing environments give us many new areas for future detailed study, deeply detailed study. We have passed the period of simple generalizing from observation and are entering the phase of complex hypotheses dependent on simplifying insights.

This book is the somewhat revised content of two symposia carefully built up by the editors, Simpson and Roe, who stress respectively as unifying threads the evolution of more complex sensing, mediating, and effector mechanisms and the evolution of greater delay and control in categories of behavior (sexual, aggressive, acquisitive, and perhaps inquisitive) within a group: thus unity comes from the biopsychological picture of the individual organism (pterobranch, ant, or man) in active relation to group and to environment. "Active relation" means a consideration of possible forces for and direction of change in all three systems, individual, group, and environment. This is more dynamic than the usual oversimplification of adaptation to an ecological niche. The participant-authors are G. G. Simpson, E. H. Colbert, A. S. Romer, F. A. Beach, E. Caspari, R. W. Sperry, K. Pribram, T. H. Bullock, H. W. Nissen, M. Bates, C. R. Carpenter, R. A. Hinde, N. Tinbergen, H. F. Harlow, W. R. Thompson, A. E. Emerson, E. Mayr, H. T. Spieth, C. S. Pittendrigh, S. L. Washburn, V. Avis, J. S. Huxley, L. Z. Freedman, Anne Roe, and M. Mead. Each gives a summary analysis on subjects ranging from phylogeny of behavior to cultural determinants of behavior.

For physical anthropologists Washburn and Avis' statement of the importance of tool-using as a selective force in human brain increase is one of the cross-sightings pointing to future analysis and experiment. The possible mode of operation and the speed of such selection receives some critical light from two of Harlow's theses: that the structural and behavioral possibilities of a species overshoot its usual behavior and that there is no quantum evolution involved in the general vertebrate phylogenetic increase in brain size accompanying more complex and flexible behavior. A most vital insight for us is Pribram's emphasis on sequential or time-dependent functions of the antero-medial thalamic nuclei, with diffuse input, linked to anterofrontal cortex as opposed to discriminative functions of lateral and posterior thalamic nuclei, with precise sensory inputs, linked to parieto-temporo-occipital cortex. This goes beyond the conventional emotional versus associational contrast of paleocortex versus neocortex in clarifying the structural changes which must accompany human behavior (language, maternal care, emotional ambivalence, and culture—cf. Huxley, Freedman and Roe, Mead). Thompson points out (partly quoting Hebb) that in higher primates and man "the same factors [i.e., larger total cortex and thalamus] that make such a degree of emotionality possible also make available the means of controlling it." Thompson and Caspari both emphasize the genetic background of behavior differences in adaptation. Beach stresses the similarity of all vertebrate hormones and their decreasing importance in sexual activity as the CNS becomes more complex. Freedman and Roe in effect carry this a stage further in pointing out how frustration and ambivalence virtually built into the human CNS lead to such key institutions as the incest taboo.

Almost all papers overtly or by implication stress that selection operates on population groups through differential fertility of individuals and not through mere survival: there is always an adaptive gap. Huxley, Mead, and Simpson point out the major shift in selection which occurs with development of a culture, the fallacy of assuming that social evolution parallels biological evolution (social Darwinism), and the need for increasing multidimensionality in study of man.

The organization of this book as a symposium, with discussion sketched only in Simpson's useful summary, makes the book difficult to read, semantically inconsistent, inconsistent in distance of speculation from data, repetitive, and kaleidoscopic in point of attack. But these stumbling blocks to quick absorption are like the delaying conversation and changes of dish in a formal dinner of many courses: they stimulate digestion. No one of the authors has written in jargon or beyond the immediate grasp of intelligent readers. Simpson has taken pains to clarify divergences in use of a term (adaptation, for example) or a new word (teleonomy). The result is a remarkable book, a true product of the 1950's and one which anthropologists will refer to increasingly as their own research gains depth in combined analysis of physiology and of social function.

J. Lawrence Angel
The Daniel Baugh Institute of Anatomy
The Jefferson Medical College
Philadelphia, Pennsylvania

THE DENTITION OF THE AUSTRALOPITHECINAE. By John T. Robinson. Transvaal Museum Memoir No. 9, 179 pp. Transvaal Museum, Pretoria, South Africa, 1956.

A most complete description and careful analysis of an important fossil hominid group is to be found in John T. Robinson's well illustrated and documented work on the dentition of the Australopithecinae. This comes as another excellent memoir from the Transvaal Museum. Robinson resists the temptation to include other related pre-hominids in the presentation, adhering strictly to his studies of the Australopithecinae.

After a brief account of the discovery of the Australopithecinae he discusses the geology and the dating of the sites as of the time of writing the book. He then moves through a description of the materials, the methods used and definitions. Then he gives an intensive and detailed description of the permanent teeth one by one. One chapter deals with the deciduous dentition, one with the special problems in the evolutionary trends and a third with hominid phylogenesis.

A total of 448 permanent teeth and 78 deciduous ones form the basis of this report. Swartkrans is represented by 273 permanent and 38 deciduous teeth, well distributed so that a good conception of the range of each type of tooth is obtained. The Sterkfontein dentition is represented by only about one half the number of teeth found at Swartkrans, but still gives representation throughout the dental arcades from incisor to third molars in sufficient numbers to give positive understandings of their size, shape and distinguishing features.

The book is filled with large excellent photographic reproduction of the various teeth, many with several views. All the photos are twice natural size and afford an accurate and detailed view of the various aspects of the teeth.

Charts of the various important measurements include comparable data from other fossils and certain modern population groups.

Disagreements regarding taxonomy need not be too troublesome in the consideration of the presentation of the dentition of Australopithecinae by Robinson. Differences between the forms are striking. Whether to ascribe specific or generic rank to them is a problem.

Several questions remain unresolved, such as the question of sexual dimorphism in these specimens. In two cases in the large Swartkrans samples some indication of this possibility is suggested. Robinson shows two histograms plotting measurements of specimens which exhibit clear bimodality. These are for the breadth of the lower first permanent molars and the maxillary canine. However, he states that more material will be required before it will be possible to determine precisely the nature and extent of sexual dimorphism in the pre-hominids. Many problems of comparative tooth morphology are discussed throughout the hook. Perhaps one of the most interesting of these involves the relative size of the anterior and posterior dentitions of Paranthopus and Australopithicus. Reference is made to the probable function of each dentition and the weight of these points in the argument for ascribing the two forms to separate genera.

One of the concluding statements of Robinson is that there is no substitute for actual specimens marking out the pathway in time. This presentation from the Transvaal Museum Memoir Series is a landmark in this pathway.

ALBERT A. DAHLBERG
Zoller Dental Anthropology
University of Chicago

HUMAN BIOCHEMICAL GENETICS. By H. Harris. Cambridge University Press. 1959.

The book by Dr. Harris fulfills a real need in a rapidly moving field of human biology. With the availability of biochemical techniques and the realization that all gene action is at the level of enzymes and proteins, human biochemical variability is being studied with increasing tempo in recent years. Dr. Harris, a human geneticist with a medical background, has been an important contributor to this field. Everyone interested in human genetics can be grateful that Dr. Harris found time from his researches to compile a most judicious count of the present status of human biochemical variation.

The book starts with a short but meaty account of genetic principles with reference to population genetics. Physical anthropologists should note that only a very slight heterozygote advantage would keep a recessive trait with 2% heterozygote frequency in stable balance. Such an advantage may be very difficult, if not impossible, to demonstrate.

The greatest part of the book is devoted to a critical exposition and discussion of well documented hereditary variants and diseases which can be studied by biochemical techniques. Dr. Harris is extremely conservative and will never go further than the actual data indicates. In contrast to many other monographs and books on human biology, this volume is singularly free of speculations or tentative interpretations. This absolute attention to facts gives the book great strength and makes it an impeccable source of guidance for interested workers. As can be expected in a rapidly moving field, many sections of the volume are already incomplete. For example, recent exciting developments in the abnormal hemoglobins and the glucose-6-phosphate dehydrogenase defects will make important additions to a second edition.

The last section of the book is devoted to a general account of gene action. Here, one wishes that Dr. Harris would have been less conservative and given the reader more indications of some of the exciting consequences of recent work in nucleic acids and proteins and their implications for human genetics.

Several other books dealing with somewhat similar material have recently appeared. A comparison therefore may be useful to interested readers confronted with several choices. Dr. Hsia's book, "Inborn Errors of Metabolism (Year Book Publishers, Chicago, 1959), is a short but not always accurate review of inherited biochemical diseases. The latter book would be most useful for rapid orientation of the busy medical student or clinician but is not useful as a reference volume except for its section on laboratory techniques. Dr. Harris' book is much more searching from the genetic viewpoint although it reflects in its emphasis the specific research interests and lack of clinical concern of the author. The Ciba Symposium on the Biochemistry of Human Genetics (Little, Brown, and Company, Boston, 1959) is a most valuable companion volume to Dr. Harris' book and brings many topics up to date. It gives much of the interpretative and speculative material missing from Dr. Harris' book. "The Metabolic Basis of Inherited Disease" (McGraw-Hill Book Company, New York, 1960) is a massive, recently published tome of encyclopedic dimensions. Its many authors emphasize the metabolic features of diseases which happen to be inherited. Treatment of biochemistry and pathophysiology is outstanding while genetic considerations of specific disease often are weak and sometimes misleading.

Dr. Harris' book remains first choice as an introduction to this area. Much of its subject matter needs to be working knowledge of every physical anthropologist in 1960.

Arno G. Motulsky

The Study of ABO Blood Groups of Sainis of Punjab

INDERA P. SINGH AND DARSHAN SINGH
Department of Anthropology, University of Delhi, Delhi, India

Sainis are a gardening and cultivating tribe found mainly in Western U. P. and Punjab. Sainis claim to have Rajput origin (according to Ibbetson). But Purser says that according to their own account they were originally malis and lived originally in Mathura District. They seem to have migrated to Punjab after the invasion of Mahmud Ghazni. The present study has been undertaken to determine the ABO blood groups among the Sainis of Punjab and to find out their relation to others.

The subjects were residents of Delhi who belong originally to various districts of Punjab (Hoshiarpur, Jullundur and Ambala). The data were collected from the homes of various subjects and tested in the Department of Anthropology. All 200 subjects studied were unrelated to each other. The technique followed was as described by Race and Sanger ('54). Sera anti-A and anti-B were procured from the Haffekine Institute, Bombay.

Table 1 shows the frequency distribution of ABO blood groups among the Sainis. We notice that B is found most frequently while A and O are also quite common.

Gene frequencies of ABO have been calculated by two methods, i.e., the approximate method of Boyd ('50) and maximum likelihood method of Stevens. The deviation was found to be 0.0136, the value of D/σ is 0.8328 which being lower than 2 shows that the result of the present study agrees with the Bernstein's theory.

Taylor and Prior's formula has been applied to test the goodness of fit of the expected and the observed phenotype frequencies. The chi^2 value obtained is 0.184 which is in agreement with Bernstein's theory.

Table 4 shows the distribution of ABO blood groups as well as gene frequencies of different groups of Punjab and U. P. The chi^2 has been calculated to test the significance of difference between these

TABLE 1

Frequency distribution of ABO blood groups among the Sainis

Total no.	Absolute numbers				Percentage			
	O	A	B	AB	O	A	B	AB
200	52	56	64	28	26.0	28.0	32.0	14.0

TABLE 2

Gene frequencies of Sainis

p	p′	q	q′	r	r′	D	σ	D/σ
0.2385	0.2369	0.2652	0.2633	0.5099	0.4997	0.0136	0.0163	0.8328

TABLE 3

Expected and observed blood groups of Sainis

Total no.	Frequency observed				Frequency expected			
	O	A	B	AB	O	A	B	AB
200	0.260	0.280	0.320	0.140	0.249	0.293	0.327	0.129

$\chi^2 = 0.184$.

TABLE 4

Comparison with others

S. no.	Population	Locality	Total no.	O	A	B	AB	p	q	r	χ^2	Author
1	Rajputs	Punjab	118	28.80	28.00	33.00	10.20	0.216	0.249	0.537	1.200	Malone and Lahiri
2	Punjabis	Lahore	204	33.33	20.59	32.84	13.24	0.215	0.252	0.531	3.756	Boyd
3	Punjabis	Peshawar	155	29.68	25.81	31.61	10.43	0.183	0.261	0.554	0.631	Boyd
4	Jats	Punjab and Kashmir	277	33.20	24.50	35.50	6.80	0.171	0.240	0.576	7.174	Malone and Lahiri
5	Kayasthas	U. P.	110	36.00	19.90	32.60	11.50	0.165	0.249	0.581	4.771	Majumdar
6	Khattris	U. P.	126	32.00	24.20	33.30	10.50	0.191	0.249	0.559	2.086	Majumdar
7	Chamars	U. P.	151	36.30	18.70	39.30	5.70	0.131	0.259	0.609	10.965	Majumdar
8	Doms	U. P. (Hill)	125	36.00	20.00	33.80	10.20	0.163	0.249	0.587	4.722	Majumdar
9	Kshattriyas	U. P.	416	30.83	26.83	32.73	9.61	0.202	0.240	0.556	3.465	Majumdar
10	Brahmins	U. P. (Gorakhpur Basti)	203	31.30	29.10	31.60	8.00	0.208	0.224	0.568	4.951	Majumdar
11	Brahmins	U. P. (Lucknow students)	186	27.80	29.40	35.80	7.00	0.205	0.247	0.548	4.520	Majumdar
12	Khatris and Aroras	Delhi	3306	29.49	21.42	40.92	8.16	0.169	0.295	0.536	11.432	Swadesh Anand
13	Sainis	Delhi	200	26.00	28.00	32.00	14.00	0.2369	0.2633	0.4997	—	Present study

groups. Sainis show significant difference only from Jats, Chamars and Khatris of Punjab. They show very non-significant difference with Rajputs of Punjab and Peshawris. They also show non-significant difference with Punjab (Boyd), Kayasthas, Khatris, Doms and Brahmin of U. P. Majumdar).

Very high B gene frequency, namely 0.2633, is noticed in our data which is consistent with the distribution of the gene in this region.

SUMMARY

Blood groups of Sainis, a gardening and cultivating tribe, have been studied. A very high B gene frequency has been noticed among them as in other Asiatic groups. They are not found to be significantly different from other groups for ABO blood groups of Punjabis.

ACKNOWLEDGMENT

We wish to express our thanks to Prof. P. C. Biswas, for the use of the Laboratory facilities and supply of sera.

LITERATURE CITED

Boyd, W. C., and L. G. Boyd 1954 The blood groups in Pakistan. Am. J. Phys. Anthrop., *12.*

Boyd, W. C. 1950 Genetics and the Races of Man. Little, Brown and Company, Boston.

Chaudhri, I. M., E. W. Ikin, A. E. Mourant and J. A. E. Walby 1952 The blood groups of the people of North-West Pakistan. Man, no. 250.

Crooke, W. 1896 The tribes and castes of N.W.F.P. and Oudh. 3.

Graval, S. D. S. 1951 Blood Groups, Blood Types, Rh, Hr, Etc., for Clinical, Forensic and Anthropological Purposes. Thacker's Press, Calcutta.

Khan, A. M. 1952 Blood group frequencies in the Punjab. The Medicus (Karachi), 5.

Macfarlane, E. W. E. 1938 Blood group distribution in India with special reference to Bengal. J. Genetics, *36.*

Majumdar, D. N., and K. Kishen 1947 Report on the Serological Survey of the United Provinces, 1941 Census. Eastern Anthropologist, *1:* No. I.

Malone, R. H., and M. N. Lahiri 1929 The distribution of the blood groups in certain races and castes of India. Ind. J. Med. Res., *16.*

Mc Arthur, N., and L. S. Penrose 1951 World frequencies of the O, A and B blood group genes. Ann. Eugen., *15.*

Race, R. R., and R. Sanger 1954 Blood groups in Man, 2nd ed. Blackwell Scientific Publications, Oxford.

Taylor, G. L., and A. M. Prior 1937–38 Blood groups in England. II. Distribution in the population. Ann. Eugen., *8.*

Swadesh, A. 1957 A genetic survey of ABO blood group among the Punjabis. The Anthropologist, *4.*

The Western Apache: Some Anthropometric Observations

BERTRAM S. KRAUS
Department of Orthodontics, School of Dentistry, University of Washington, Seattle, Washington

In comparison with the scope of archaeological, linguistic, and social anthropological investigations undertaken in the American Southwest the anthropometry of the living Indian populations of this area has been remarkably circumscribed. Spuhler ('54) and Gabel ('49) have cited what meager data are available, including the early reports of Hrdlička ('00, '08, '09). In the past 25 years the major published studies are those of Gabel ('49) on the Papago, Seltzer ('36) on the Yaqui, and Hrdlička ('35) on the Pueblos. The data on the Ramah Navaho gathered by Spuhler and Kluckhohn, as yet unpublished, should be an important addition to the anthropometric literature of the Southwest. With the increasing interest in traits whose heritability and mode of inheritance are known (e.g., blood groups, PTC taster) emphasis has shifted problemwise to the genetic structures and mutability of populations as breeding units. Nevertheless, the classic interest of physical anthropology in the morphological polymorphism and polytypism of man can be expected to continue, although the frame of reference may, as is fitting, change with the times.

The present paper adds some recent anthropometric data to the existing pool of information and attempts to interpret their meaning both within the population studied and against the background of neighboring Southwestern Indian populations.

THE DATA

In the summer of 1954 a survey was conducted among the Indians of the Fort Apache Reservation in east-central Arizona to investigate the incidence of congenital dislocation of the hip (Kraus and Schwartzmann, '57) and to determine whether or not separate breeding populations existed on the reservation (Kraus and White, '56). In addition to various serological, dental, and medical data, certain physical dimensions were recorded. The latter, not reported in the two papers cited, included: height, weight, head length, head breadth, and bizygomatic breadth. Height was taken with an anthropometer, with the subject's shoes removed and the head held in a Frankfort-Horizontal. Head and face breadths were taken with a spreading caliper. Scales available in the various clinics throughout the reservation were utilized in recording weights. Only the subject's shoes were removed.

A total of 626 subjects were observed, ranging in age from 1–65 years. The classification of the sample by age and sex was as follows:

Age	No. females	No. males
years		
1	5	1
2	9	16
3	14	18
4	15	16
5	19	17
6	23	14
7	12	16
8	14	13
9	11	13
10	11	8
11	14	5
12	17	8
13	6	6
14	11	4
15	10	2
16	4	4
17	5	2
18	8	2
19	1	1
20+	165	86
Total	374	252

Three distinct breeding groups corresponding to three endogamous bands had been described (Kraus and White, '56). The villages of Whiteriver, East Fork, North Fork, and Seven Mile are included in the Eastern band; Cedar Creek and Canyon Day are the principal villages of the Western band; Cibecue is the headquarters of the Cibecue band in the western portion of the reservation. The distribution of the adult members of the sample (20+ years of age) according to village of residence is as follows:

Village	No. males	No. females
Whiteriver[1]	32	48
Cedar Creek	16	21
Canyon Day	0	67
Cibecue	32	28
Other	6	1
Total	86	165

[1] Includes East Fork, North Fork, and Seven Mile.

Intragroup results

No attempt was made to analyze the data from ages 1–19 by individual bands because of the resultant inadequacy of the sample. The mean values for height and weight for boys and girls from 1–19 years of age are presented in table 1. E cept for ages 6, 7, 9, and 12, boys are co sistently taller than girls of the same ag On the other hand, Apache girls are co sistently heavier than boys of the sam age throughout the entire period. Fema adults are, on the average, 10 poun lighter than male adults, the mean weigh being 142.8 lbs. and 152.3 lbs. respe tively. The mean stature of adult mal was 167.6 cm and of adult females 152 cm, with a mean difference of 14.8 cm approximately 6 inches.

Means and standard deviations for hea length, head breadth, and bizygomat breadth are given in table 2 for girls ar boys from 1–19 years of age. There appea to be no significant difference between th sexes in growth patterns, growth rates, absolute dimensions with respect to thes three head diameters. However, it must b remembered that the data are cross-se tional and hence lack the power of di crimination in the absence of very larg sample size.

When the adults are grouped accordin to village of residence, the results in term of means and standard errors of hea length and breadth, bizygomatic breadt

TABLE 1

Means and standard deviations of heights and weights of Apache males and females from 1–19 years of age

Age	Height				Weight			
	Males		Females		Males		Females	
	No.	Mean ± S.D.	No.	Mean ± S.D.	No.	Mean ± S.D.	No.	Mean ± S.
years		*mm*		*mm*		*pounds*		*pounds*
1	1	820	5	712 ± 31.1	3	15 ± 2.5	6	23.0 ± 2.
2	16	818 ± 73.6	9	812 ± 65.1	4	22 ± 3.3	12	26.1 ± 6.
3	18	921 ± 44.2	14	910 ± 56.6	11	24 ± 3.6	14	29.5 ± 3.
4	16	999 ± 63.8	15	971 ± 116.4	19	32 ± 3.1	14	35.1 ± 7.
5	17	1075 ± 43.9	19	1041 ± 33.6	16	39 ± 4.8	18	40.8 ± 3.
6	14	1080 ± 34.4	23	1120 ± 61.8	17	41 ± 4.8	23	46.3 ± 7.
7	16	1156 ± 62.1	12	1186 ± 40.3	14	42 ± 3.9	12	50.4 ± 10.
8	13	1247 ± 50.7	14	1212 ± 75.4	16	49 ± 7.4	13	52.5 ± 10.
9	13	1291 ± 42.2	11	1294 ± 62.0	13	58 ± 7.2	11	62.0 ± 11.
10	8	1345 ± 54.2	11	1318 ± 55.3	13	63 ± 9.8	11	65.8 ± 12.
11	5	1416 ± 60.7	14	1376 ± 111.3	8	66 ± 7.5	15	74.6 ± 15.
12	8	1427 ± 91.5	16	1470 ± 64.6	5	78 ± 10.2	17	89.9 ± 16.
13	6	1502 ± 88.0	6	1470 ± 99.8	8	79 ± 11.5	6	95.0 ± 18.
14	4	1567 ± 107.2	11	1524 ± 41.1	6	86 ± 9.8	10	113.1 ± 15.
15	2	1680	10	1542 ± 58.8	5	100 ± 33.0	10	115.3 ± 14.
16	4	1687 ± 41.2	4	1515 ± 25.2	2	120	4	112.2 ± 17.
17	2	1720	5	1522 ± 21.7	3	120 ± 18.0	5	122.8 ± 15.
18	2	1680	8	1565 ± 20.7	2	138	7	130.0 ± 12.
19	1	1720	1	1580	2	139	1	117.0

TABLE 2

Means and standard deviations of head dimensions of Apache males and females from 1–19 years of age

Age	Head length		Head breadth		Bizygomatic breadth	
	No.	Mean ± S.D.	No.	Mean ± S.D.	No.	Mean ± S.D.
years		*mm*		*mm*		*mm*
			Males			
1	6	148.5 ± 5.9	6	137.0 ± 23.5	5	112.6 ± 8.7
2	14	158.2 ± 6.2	14	135.4 ± 8.7	14	110.7 ± 6.4
3	19	160.1 ± 7.9	19	140.8 ± 7.0	19	114.9 ± 6.3
4	16	159.1 ± 9.6	16	145.4 ± 4.7	16	118.5 ± 3.9
5	20	164.9 ± 10.3	20	146.9 ± 6.6	20	121.3 ± 5.8
6	15	164.5 ± 7.2	15	146.8 ± 4.6	15	121.9 ± 4.4
7	17	165.1 ± 8.1	17	148.5 ± 7.4	17	125.7 ± 7.6
8	12	170.5 ± 5.0	12	151.3 ± 4.8	12	129.2 ± 5.0
9	13	171.1 ± 7.6	13	150.5 ± 5.7	13	128.6 ± 4.3
10	8	169.5 ± 4.3	8	151.6 ± 6.6	8	127.0 ± 7.1
11	5	169.4 ± 8.4	5	158.0 ± 4.6	5	136.4 ± 3.1
12	8	175.1 ± 7.2	8	151.7 ± 7.9	8	131.9 ± 5.4
13	6	174.3 ± 9.9	6	151.5 ± 3.6	6	132.7 ± 3.1
14	5	172.0 ± 8.4	5	157.8 ± 6.8	5	139.2 ± 7.2
15	2	173.5	2	161.5	2	146.5
16	4	178.2 ± 5.9	4	161.0 ± 5.4	4	143.5 ± 4.2
17	2	183.5	2	163.0	2	146.5
18	2	183.0	2	162.0	2	140.5
19	1	182.0	1	153.0	1	145.0
Total	175		175		174	
			Females			
1	7	149.7 ± 8.4	7	133.4 ± 6.5	7	110.1 ± 4.0
2	11	155.1 ± 4.9	11	134.3 ± 7.0	9	112.5 ± 5.2
3	14	156.3 ± 5.3	14	136.3 ± 5.2	12	112.2 ± 2.6
4	15	158.3 ± 8.8	15	139.5 ± 7.5	15	116.2 ± 5.8
5	18	160.3 ± 7.2	18	143.0 ± 5.2	18	117.5 ± 4.3
6	23	161.9 ± 5.4	23	144.0 ± 4.5	23	120.6 ± 3.5
7	12	165.1 ± 6.8	12	145.2 ± 6.3	12	123.6 ± 5.1
8	13	164.1 ± 5.0	13	146.3 ± 5.7	13	123.2 ± 5.1
9	12	165.4 ± 8.5	12	148.8 ± 7.1	12	128.6 ± 4.5
10	11	166.5 ± 8.3	11	152.1 ± 3.4	11	131.2 ± 4.5
11	15	167.3 ± 8.1	15	150.2 ± 6.5	15	131.8 ± 4.4
12	17	168.2 ± 6.4	17	151.0 ± 5.4	17	133.3 ± 3.9
13	6	172.0 ± 3.4	6	156.2 ± 3.5	6	136.8 ± 8.2
14	10	171.7 ± 4.4	10	153.4 ± 5.6	10	136.4 ± 5.1
15	10	172.4 ± 4.7	10	154.5 ± 5.0	10	140.4 ± 8.8
16	4	176.0 ± 2.2	4	150.2 ± 8.8	4	139.5 ± 11.0
17	5	174.2 ± 7.0	5	157.6 ± 2.3	5	142.6 ± 5.3
18	7	175.7 ± 6.4	7	156.4 ± 4.5	7	144.6 ± 3.5
19	1	182.0	1	147.0	1	132.0
Total	211		211		207	

nd stature are as presented in table 3. It ill be observed that in all instances the ean dimensions of all male groups ex- eeded those of all female groups with spect to each of the 4 types of obser- ation. The weighted male mean for head ngth was 182.8 mm compared with the male mean of 176.0 mm. The male eans for head breadth and bizygomatic eadth were 161.0 mm and 149.0 mm spectively; for the females, 157.5 mm and 141.5 mm respectively. The 4 sets of differences between males and females were statistically significant at the 5% level. In terms of the arithmetic mean, therefore, Apache adult males are significantly taller and heavier, and have longer and broader heads and broader faces than Apache adult females.

Serological tests had revealed significant differences between the three bands—Eastern, Western, and Cibecue—in gene

TABLE 3

Means and standard errors of adult measurements by villages

Males 20 Years of Age and Over

Observation	Village		
	Cedar Creek	Whiteriver	Cibecue
Head length	(16) 181.81 ± 1.77	(32) 183.84 ± 1.13	(32) 182.22 ± 1.18
Head breadth	(16) 162.06 ± 1.62	(32) 160.47 ± 1.11	(32) 161.06 ± 1.12
Bizygomatic breadth	(16) 148.62 ± 1.68	(32) 147.72 ± 1.07	(32) 150.47 ± 1.08
Stature	(15) 1684.7 ± 21.3	(31) 1683.9 ± 11.4	(32) 1665.3 ± 10.6

Females 20 Years of Age and Over

Observation	Village			
	Cedar Creek	Whiteriver	Cibecue	Canyon Day[1]
Head length	(21) 174.86 ± 1.33	(46) 175.11 ± 0.91	(25) 178.80 ± 1.42	(67) 177.12 ± 0.80
Head breadth	(21) 156.67 ± 1.12	(46) 155.13 ± 0.84	(25) 157.41 ± 1.80	(67) 159.39 ± 0.67
Bizygomatic breadth	(20) 139.80 ± 1.37	(48) 141.62 ± 0.87	(25) 143.64 ± 0.91	(67) 141.18 ± 0.74
Stature	(19) 1517.4 ± 11.5	(46) 1533.3 ± 7.9	(28) 1537.5 ± 7.7	(66) 1523.5 ± 5.6

[1] Adult males were not examined at Canyon Day.

frequencies at the ABO and Rh loci. These differences were explained on the basis of genetic drift since sociological and historical evidence point to conditions under which genetic drift may operate with maximum effect, i.e., small band size and endogamous breeding. In view of the apparent differences in the genetic pools of the three bands, a question might be raised. Do measurements of gross morphology reflect these populational differences in gene frequencies?

Paired village (band) comparisons of means for both males and females are presented in table 4. The males from Cedar Creek, Whiteriver, and Cibecue do not differ significantly from each other in any of the 4 traits observed. Among females only 4 comparisons out of a possible 24 show significant differences and no two of these are found within a single pair. What is more, there is no systematic distribution of the 4 significant differences, either by band or by trait. There are no differences between Cedar Creek and Whiteriver females, or between Cib cue and Canyon Day females. Both Ced Creek and Whiteriver females differ si nificantly from Canyon Day females on in head breadth; this in spite of the fa that the populations of Cedar Creek an Canyon Day are members of the same band and intermarry with high frequenc Whiteriver and Cibecue females differ si nificantly in head length; Cedar Creek an Cibecue females differ significantly in b zygomatic breadth.

The "t" test, of course, simply estimates the probability of a stated difference b tween means occurring by chance. Failu to demonstrate significance should not e courage the assumption that the two pop lations compared are similar. In fact, they might be of an entirely different compos tion in terms of internal variability, y the means may be identical. Oliver an Howells ('57) have shown quite convin ingly in a study of breeding population in Bougainville the limitations in interpr tation of anthropometrical statistics base

TABLE 4

Statistical comparison of Apache males and females by villages

Paired villages	Observation	Males			Females		
		$\bar{x}_1 - \bar{x}_2$	t Value[1]	P	$\bar{x}_1 - \bar{x}_2$	t Value[1]	P
		mm			*mm*		
edar Creek	Head length	2.03	1.00	> 0.30	0.25	0.15	> 0.90
hiteriver	Head breadth	1.59	0.81	> 0.40	1.54	1.03	> 0.30
	Biz. breadth	0.90	0.45	> 0.60	1.82	1.10	> 0.20
	Stature	0.8		> 0.90	15.9	1.09	> 0.20
edar Creek	Head length	0.41	0.19	> 0.90	3.94	2.00	> 0.05
becue	Head breadth	1.00	0.54	> 0.50	0.74	0.33	> 0.50
	Biz. breadth	1.85	0.93	> 0.30	3.84	2.28	< 0.05[2]
	Stature	19.4	0.89	> 0.30	20.1	1.52	> 0.10
hiteriver	Head length	1.62	0.97	> 0.30	3.69	2.25	< 0.05[2]
becue	Head breadth	0.59	0.37	> 0.70	2.28	1.28	> 0.20
	Biz. breadth	2.75	1.77	> 0.05	2.02	1.40	> 0.30
	Stature	18.6	1.19	> 0.20	4.2	0.35	> 0.70
edar Creek	Head length				2.26	1.37	> 0.10
anyon Day	Head breadth				2.72	2.01	< 0.05[2]
	Biz. breadth				1.38	0.89	> 0.30
	Stature				6.1	0.49	> 0.60
hiteriver	Head length				2.01	1.62	> 0.10
anyon Day	Head breadth				4.26	3.98	< 0.01[2]
	Biz. breadth				0.44	0.39	> 0.60
	Stature				9.8	1.03	> 0.30
becue	Head length				1.68	1.05	> 0.20
anyon Day	Head breadth				1.95	1.24	> 0.20
	Biz. breadth				2.46	1.80	> 0.05
	Stature				14.0	1.40	> 0.10

[1] “t” Test, using pooled sum of squares and degrees of freedom.

[2] Significant differences.

pon the “F” and “t” tests. Many of the
sults of variance tests, they found, fitted
neither genetic theory nor previous an-
ropometric information.” On the other
and “these complications” contrasted
ith “the pattern of differences between
e two main groups.” The authors advise
ysical anthropologists to “turn their at-
ntion to the precise modes of differentia-
on in physique and to the specific nature
behavior of different ‘measurements’ or
aits.”

Table 5 presents the ratio of variances
etween each pair of villages for stature
nd the three head measurements. In no
stance is there a significant difference
etween variances. Insofar as internal
riability is descriptive of population
ructure, there are no demonstrable dif-
rences between the Eastern, Western, or
becue bands. From the point of view
anthropometric variability the three
nds represent one and the same population. In terms of their means only 4 significant differences are found out of 36 comparisons, so that there is no support for an argument of band differentiation.

It is extremely doubtful if these statistics contribute anything substantial to our knowledge of the populational structure of the Western Apache. Out of the total of 36 P vales only 4 are less than 0.05 and of these only one is less than 0.01. The distribution of the 36 P values permits us to regard the 4 significant values as within the limit accountable for by chance alone. Apparently, then, these selected anthropometric observations are too gross to reflect slight but significant differences in gene frequencies which are known to characterize the three bands.

Comparisons with other populations

Because of the general lack of uniformity of data, statistical treatment, and sampling procedures in the various published

TABLE 5

F ratios[1] *for inter-village comparisons*

Between villages	Stature	Head l.	Head b.	Bizyg. b.
	Males			
Cedar Creek-Whiteriver	1.77	1.22	1.05	1.23
Cedar Creek-Cibecue	1.91	1.12	1.03	1.21
Cibecue-Whiteriver	1.08	1.09	1.02	1.02
	Females			
Cedar Creek-Whiteriver	1.13	1.03	1.24	1.03
Cedar Creek-Cibecue	1.53	1.35	1.31	1.42
Cedar Creek-Canyon Day	1.21	1.16	1.14	1.03
Whiteriver-Cibecue	1.73	1.32	1.06	1.37
Whiteriver-Canyon Day	1.37	1.13	1.09	1.00
Cibecue-Canyon Day	1.26	1.17	1.15	1.38

[1] P values are not given since all are over 0.05.

studies on the somatology of Southwestern Indian populations, and because of the large time span involved in the undertaking of these investigations, it is questionable if comparative tables utilizing such data are potentially of much value. If the biological divergence of two populations is obvious on historical, linguistic, ethnological, and gross morphological grounds, such as with Chinese and Negroes, then significant anthropometric differences are easily demonstrable. But when two populations from the same racial stock, such as Papago and Apache, or even Apache and Mongols, are compared, it is a moot point whether or not the anthropometric approach is sensitive enough to detect genetic divergence.

Gabel's demonstration of "real and significant" differences between Papago and Yaqui by comparing the expected and observed distribution of the probable errors of the means of 35 traits is statistically sound but leaves a question as to the independence of the 35 traits (Boyd, '50, p. 25). Perhaps the inherent difficulty in interpreting and genetically or developmentally weighting the various comp nents of the body as expressed in line diameters will discourage further attemp to extend the application of anthropo etry beyond its potentialities.

A comparison of the means of Apach African Negro, and American Whites rea ily illustrates the ease with which the three representatives of the major raci stocks can be distinguished on the bas of only 5 body meaurements (table 6 On the other hand, when comparing rep sentatives of the Mongoloid populatio (table 7), it is difficult to find decisive d ferences in head dimensions. On the bas of greatest similarity one might group gether the Navaho and Mongols, the P pago and Yaqui, or the Apache and Na aho. Since the degree of stability of the mean dimensions from generation to ge eration is not known, statistical sign cance cannot be translated into biologic significance. On the other hand it is w known that the difference between mea when comparing Mongoloids with Cauc soids, remains relatively constant gener tion after generation.

TABLE 6

Mean dimensions of Apache, African Negro, and American White males

Measurements	(Present study) Apache	(Oschinsky, '54) African Negro	(Hooton and Dupertuis, '51) Irish White
Stature	168	157.3	172.0
Weight	152		157.4
Head length	182	186.2	195.7
Head breadth	161	148.0	154.0
Bizyg. breadth	148	139.2	140.7

TABLE 7

Mean dimensions of Apache and other Mongoloid groups

Population	Source	Stature	Head l.	Head b.	Bizyg. b.
Apache	Present study	168.0	182.0	161.0	149.0
Papago	Gabel ('49)	168.8	186.7	150.2	142.2
Yaqui	Seltzer ('36)	166.7	183.0	149.2	141.0
Comanche	Goldstein ('34)	168.3	191.7	160.3	154.4
Navaho	Seltzer (Gabel, '49)	169.6	184.9	158.9	146.3
Jehol Mongols	Yokoh ('43)	165.0	184.6	156.3	142.9
Japanese	Kraus ('59)	160.4	188.3	154.0	143.6

A somewhat different picture is pre- nted when anthropometry is applied to e study of growth. Here each dimension presses the cumulative effect of increase size at any given moment in time. Since owth is more patently under genetic con- ols, it might be expected that growth cords, whether longitudinal or cross-sec- onal, will reflect actual hereditary dif- rences if such do exist. Studies utilizing ly height and weight have shown sig- ficant differences in the pattern and tes of growth between Papago and ache children, while pointing up the sential similarity between Papago and ma who are known to have close bio- gical affinity (Kraus, '54). Frequency stributions of the genetically controlled rabelli trait have likewise distinguished tween Apache and Papago, while sug- sting Papago and Yaqui affinity (Kraus, 9).

Figures 1 and 2 plot the mean weights d heights, respectively, of Apache boys d girls from 1–19 years of age and compare them with White and Negro girls from 6–14 years of age (Krogman, '59). Until the age of 16 the mean weight of Apache girls is greater than that of boys at corresponding ages. In the period from 6–14 years there is no difference in means or rates between Apache girls and Negro and White girls. In stature Apache boys and girls show the same means and rates of growth until the age of 13 when boys show a definite spurt while girls level off, having achieved at this time the mean stature found in adult females. Again, there is no differentiation between Negro and White females in growth in stature and Apache males or females, from the ages 6–14.

Figures 3–5 plot means of head length and head and face breadths for Apache girls from 1–19 and compare with these the values for Negro and White girls from 6–14. As Krogman ('59) points out, "for all practical purposes there are no group differences in any of the head measurements" (referring only to Negroes and

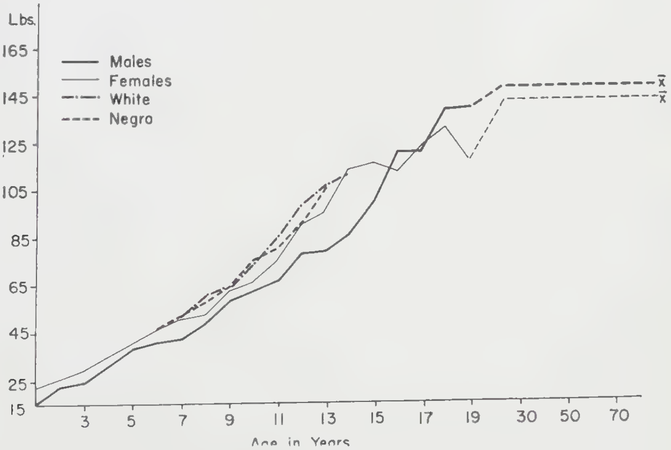


Fig. 1 Apache males and females by age and weight.

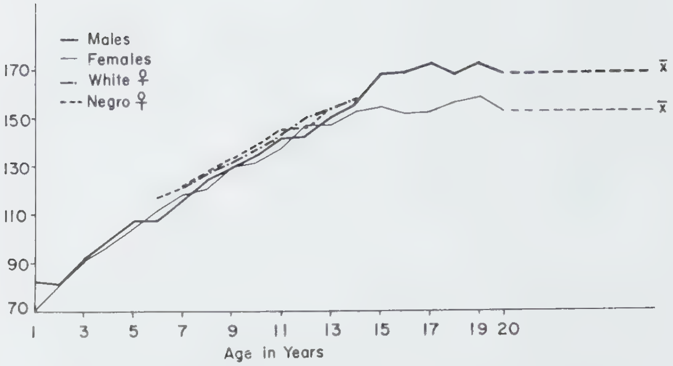


Fig. 2 Apache males and females by age and height.

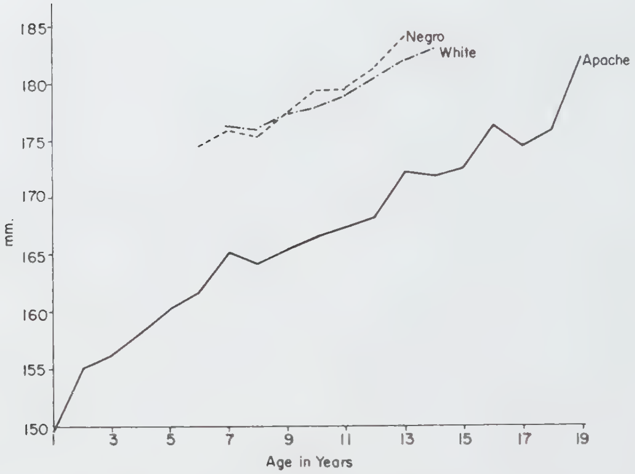


Fig. 3 Increase in head length of Apache, White, and Negro females from 1–19 years of age.

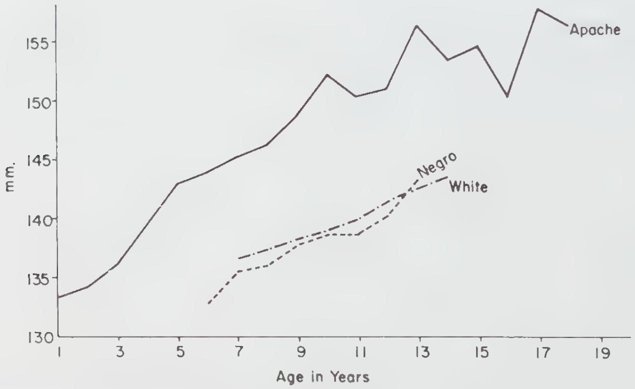


Fig. 4 Increase in head breadth of Apache, White, and Negro females from 1–19 years of age.

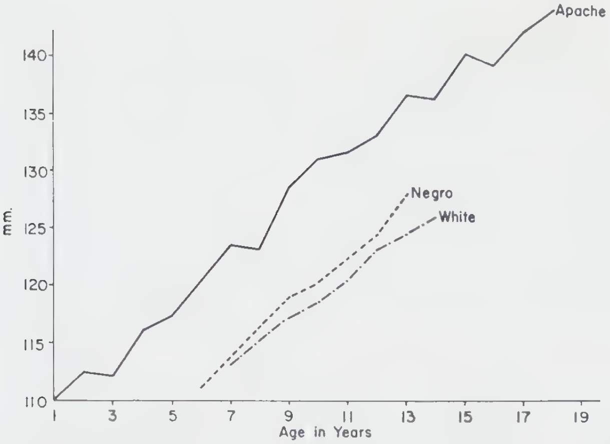


Fig. 5 Increase in bizygomatic breadth of Apache, White and Negro females from 1–19 years of age.

Vhites). In all three dimensions, howver, the Apache girls show striking diferences. In head and face breadth Apache irls are, at all ages, significantly lower in ean values than Negro and White girls. n head length they are significantly igher at all comparable ages. There are o apparent differences in rates of growth s indicated by slope of the regression line. his can be interpreted in only one way. he significant differences in these three imensions that are shown to exist beween Apache and White adults (see table) are already apparent in children of the wo groups as early as 6 years of age. This nding is consistent with the conclusions rawn from an earlier study (Kraus, '54, . 128). of Apache, Pima, and Papago rowth:

> "A wide gulf separates Pima and Papago atterns of child development from those f Apache as well as of White patterns. n general the stocky and obese body uilds that are so characteristic of adult 'ima and Papago are already foreshadwed in 6 year old children and attained n large measure by the age of 11. Data athered on the growth of these children rom 11 to 14 years of age fail to show nything but a continuation of the trends lready established in the 6 to 11 year eriod."

SUMMARY AND CONCLUSIONS

Records of height, weight, head length, nd head and face breadth of 626 Fort Apache Reservation Indians from 1–65 years of age were made. The adult sample was divided according to affiliation with each of the three endogamous bands (breeding populations) on the reservation, and between-band comparisons were made. Comparisons of the combined adult Apache data were made with those of samples from the Negroid (Congo Baamba) and Caucasoid (Irish) racial stocks. In addition the Apache were compared with other Mongoloid groups, including certain Southwestern Indian populations. The means of 4 of these dimensions were plotted for both boys and girls from ages 1–19 and compared with similar data derived from Negro and White samples in the age group 6–14.

It was found that although significant differences in serological gene frequencies have been shown to exist among the three Apache bands, an analysis of both variances and means fails to reflect these differences anthropometrically. The weighted means of the three bands show that males exceed females in all 5 observations. On the other hand, no significant differences in growth rates or patterns between boys and girls were observed with respect to dimensions of the head but Apache girls are heavier than boys of the same age throughout the growth period 1–19 years.

The 5 measurements easily separate representatives of the three major racial stocks (Apache, Congo Negro, and Irish) but fail to distinguish biological affinities among populations drawn from a single racial stock (Mongoloid). In terms of growth, however, Apache children as early as 6 years of age are differentiated from Negro and White children in much the same way as are the adult members of these groups. Otherwise there appears to be no differences among the three stocks in growth rates or patterns between the ages of 6–14.

LITERATURE CITED

Boyd, W. 1950 Genetics and the Races of Man. D. C. Heath and Co., Boston.

Gabel, N. 1949 A comparative racial study of the Papago. Univ. N. Mex. Publ. in Anthrop., no. 4.

Goldstein, M. 1934 Anthropometry of the Comanches. Am. J. Phys. Anthrop., *19:* 289–319.

Hooton, E., and C. Dupertuis 1951 Age changes and selective survival in Irish males. Studies in Physical Anthropology, no. 2. Am. Assn. Phys. Anthrop. and Wenner-Gren Foundation for Anthrop. Res.

Hrdlička, A. 1900 Physical and physiological observations on the Navaho. Am. Anthrop., *2:* 339–345.

Kraus, B. 1959 Anthropometry of the Japanese of Northern Honshu. Unpublished data.

——— 1954 Indian Health in Arizona. Second Ann. Rep., Bureau Ethnic Res., University of Arizona, Tucson.

Kraus, B., and C. White 1956 Micro-evolution in a human population: a study of social endogamy and blood type distributions among the Western Apache. Am. Anthrop., *58:* 1017–1043.

Kraus, B., and J. Schwartzmann 1957 Co genital dislocation of the hip on the Fo Apache Indian Reservation. J. Bone Joint Surg *39A:* 448.

Krogman, W. 1959 The growth of the hea and face in American White and America Negro Boys and Girls of Philadelphia, ag 6–14 years. Mimeographed Report, Philade phia Center for Research in Child Growt

Oliver, D., and W. Howells 1957 Micro-evol tion: cultural elements in physical variatio Am. Anthrop., *59:* 965–978.

Oschinsky, L. 1954 The Racial Affinities of th Baganda and Other Bantu Tribes of Britis East Africa. W. Heffer and Sons, Ltd., Can bridge.

Seltzer, C. 1936 Physical characteristics c the Yaqui Indians. Texas Tech. Coll. Bull *12:* 91–113.

Spuhler, J. 1954 Some problems in the phy ical anthropology of the American Southwes Am. Anthrop., *56:* 604–625.

Yokoh, Y. 1943 Beiträge zur physischen an thropologie der Mongol. Anat. Inst. Toky Kaiserlichen Univ., Tokyo.

——— 1908 Physiological and medical obse vations among the Indians of the Southwester United States and Northern Mexico. Bull. Bu Am. Ethn., no. 34.

——— 1909 On the stature of the Indian of the Southwest and of Northern Mexic In: Putnam Anniversary Volume: Anthrop logical Essays, pp. 405–426, New York.

——— 1935 The Pueblos. Am. J. Phys. A throp., *20:* 235–460.

——— 1959 Height, weight, and bodily growt of American White and American Negro Bo and Girls of Philadelphia, age 6–14 year Mimeographed Report, Philadelphia Center fc Research in Child Growth.

he Reassessment of the Age and Sex of the Indian noll Skeletal Population: Demographic and ethodological Aspects

FRANCIS E. JOHNSTON AND CHARLES E. SNOW
Philadelphia Center for Research in Child Growth and Department of Anthropology, University of Kentucky

The purpose of this paper is to report e results of a reassessment of the age d sex of the Indian Knoll skeletal popu- ion. This large group of skeletons, prob- ly the largest racially homogeneous llection in North America, has been eviously described in detail (Snow, '48), sed upon a study begun in 1941.

In the original study, only one primary of aging criteria was utilized for the ult group: cranial suture closure; on s basis, the demographic description s made. However, the present reassess- ent, carried out by the authors in the mmer and fall of 1959, was based upon composite of criteria, as it is felt that entire skeleton is better than any one rt in judging age at death (Brooks,). This paper is therefore of interest t only because it presents new demo- phic information on this large prehis- ic American Indian skeletal series, but o in that it presents a comparison of o evaluations of age of the same ies involving differing methodological proaches.

In addition, data will be presented rela- e to the use of dental attrition in the luation of skeletal age. The authors ieve that, when certain conditions are t, the degree of tooth wear may be used a supplementary indicator of age.

The site

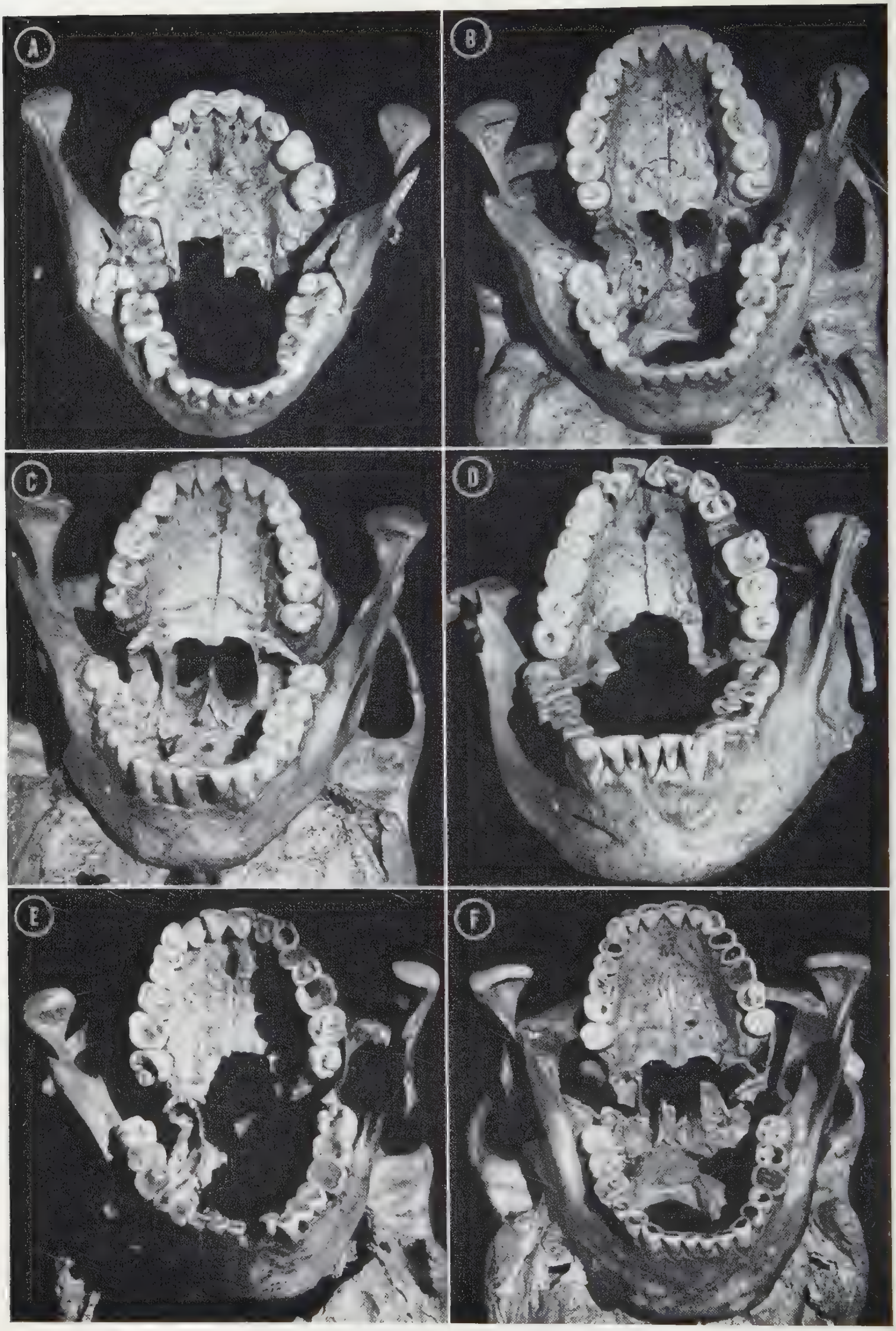
The name Indian Knoll refers to a pre- toric "shell heap" located on the banks the Green River in west-central Ken- ky. This site has yielded not only abun- nt skeletal material but also numerous ltural artifacts: some 67,000 separate ms have been catalogued. Carbon-14 dates obtained from excavated material have given an average of 5302 years (Libby, '55). This dating, plus analyses of the cultural manifestations, has served to place Indian Knoll in the Archaic period of Eastern archaeology, a period characterized by the use of ground stone but lacking agriculture, pottery, and perhaps the bow and arrow. (Spearthrowers, however, were used by the people.)

The first excavation of the site occurred in 1915 when C. B. Moore of Philadelphia removed 298 burials. Of those that are still preserved, most are located at the U.S. National Museum. During the WPA-sponsored investigations of the 1930's the investigation was completed, except for a very small area (Webb, '46). The total number of skeletons from both excavations, has been listed by Snow ('48, p. 384) to be derived from at least 1234 individuals.

In his description of the skeletal remains, Snow has pictured the people as being slender and gracile and about the size of the modern Hopi Indians of the Southwest. He further characterizes them (p. 401) as having high-vaulted heads, prognathous faces, moderately-protruding cheekbones, and a strongly-everted gonial region. Morphologically, Snow's Indian Knoll type belongs to the Amerindian race of the Mongoloid stock, and more specifically, to Neumann's Sylvid (now Iswanid) type (see Neumann, '52, pp. 17 ff.).

METHODS

Only those skeletons preserved at the University of Kentucky Museum of Anthropology were re-examined. This included some 880 documented burials


A
B
C
D
E
F

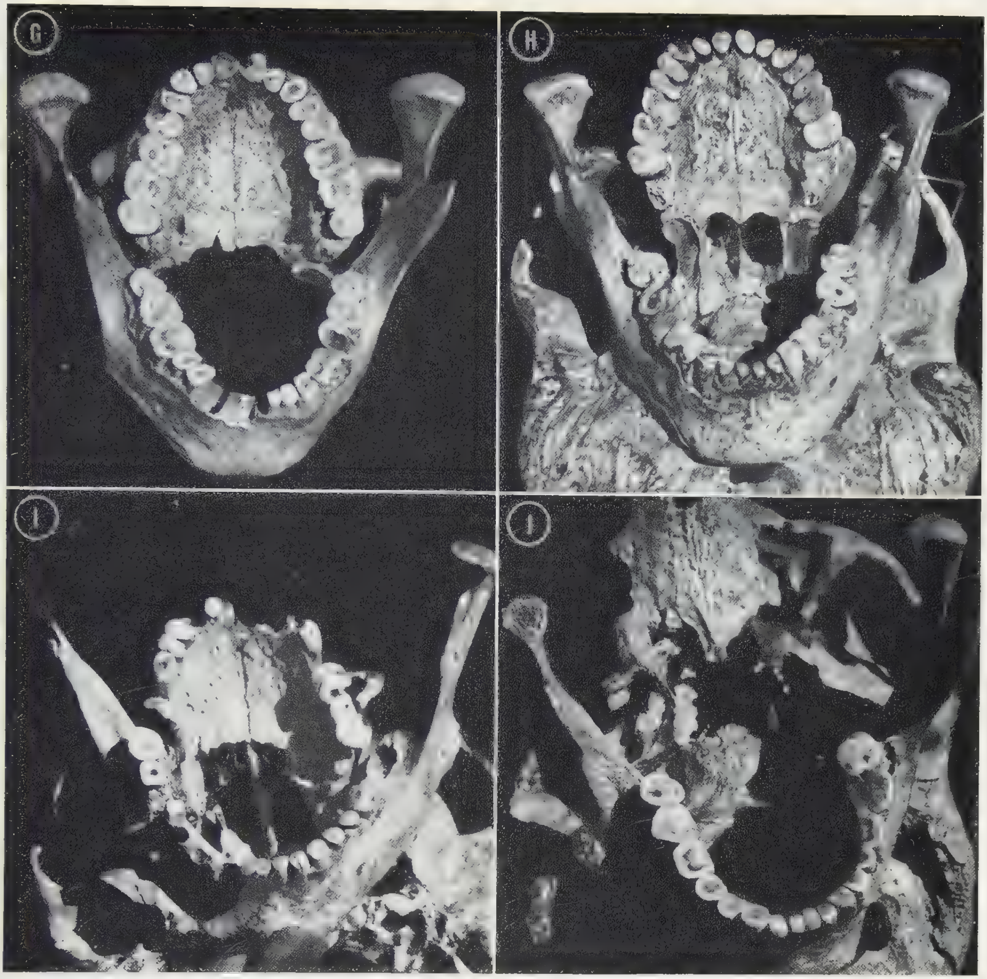


Fig. 1 Increasing tooth wear and associated age at Indian Knoll. A, no. 691, 5 years; B, no. 501, 19 years, female; C, no. 701, 21–22 years, female; D, no. 611, 26 years, male; E, no. 821, 28–29 years, female; F, no. 860, 30 years, female; G, no. 690, 30–33 years, female; H, no. 661, 35 years, male; I, no. 685, 35–40 years, female; J. no. 705, 45–50 years, male.

d fragments, largely cranial, of 48 hers removed by the University party. hese fragments were attributed to oore's investigation and were labeled .A.," i.e., "material from previously dis- rbed area." Post-cranial DA fragments ere not included in this study because eir associations could not accurately be etermined. Still others were omitted from is paper either because they were on an or simply missing. (Their storage ace has been changed several times over e years.)

The authors independently assessed the e and sex of each skeleton. The results were then compared and differences resolved. Only after a final decision had been made was the original 1941 evaluation noted.

For all ages, sexing involved primarily the pelvis, although the skull and long bones were also examined. In those cases where a definite assignment could not be made, a reasonable approximation was felt to be better than a mere question mark. Sexual dimorphism, especially in the pelvis, was marked at Indian Knoll, and hence the uncertainties were almost entirely limited to the infant and small children. In spite of the demonstration of sexual differences in the infant pelvic girdle (Reynolds, '45), approximately 18% of the Indian Knoll infants were placed into an undetermined category; the figure for the entire series was 5%.

The criteria for exact aging varied, of course, with the particular age group to which the individual belonged, and also with the degree of preservation of the skeleton. Both dental (tooth eruption and, to some extent, attrition) and skeletal (developmental age-associated indicators) information was considered. Standards for the public symphyseal surfaces presented by McKern and Stewart ('57) were utilized. Tooth calcification (third molar) was also used in the sub-adult range (Johnston, '61).

In each case, the final assessment was based upon as many of the criteria as were available. Degree of closure of the vault sutures was not observed except when extreme fragmentation necessitated it.

Dental attrition was employed at all ages as an accessory means of age estimation. The standards of wear of Leigh ('28) were followed. The extreme wear has been well described by the same author ('25). In spite of laboring under the misapprehension that these people were a late pre White contact group that practiced agriculture, Leigh's summary of the extreme conditions he observed are very complete. He says that "the writer has never seen lesions of attrition so gener ized, developed so early in life and wi such far-reaching pathological results in the crania of these Kentucky peopl (p. 185).

The attrition associated with advanci age is shown in figure 1. The extre range of wear made it possible to use su cessive exposure of the dentine and pu cavity as an indicator of age. Howeve it must be emphasized that these sort criteria are valid only within the conte of the particular series under observatio and only in conjunction with other appr priate indicators, when available.

RESULTS

Demographic aspects

The total number of burials examin in the second (1959) assessment was 873 of which 48 were from the "disturb area." Table 1 shows the number of ind viduals in 1959 and 1941 in each age cat gory, while table 2 indicates the brea down of the results of the 1959 investig tion by sex.

A high rate of infant mortality is ind cated for the Indian Knoll populatio when it is noted that 20.48% of the tot are in the under one year age group. Oth peaks are at 25–29 years (14.06%) an 30–34 years (14.91%).

The average age of the entire series the 1959 investigation, including the D

TABLE 1

Grouping of estimated ages of Indian Knoll series, 1941 and 1959

Age	1941[1] No.	1941[1] %	1959[1] No.	1959[1] %
years				
Under 1	170	15.1	170	19.47
1–4	167	14.9	84	9.62
5–9	94	8.5	54	6.19
10–14	97	8.5	53	6.07
15–19	96	8.5	59	7.15
20–24	271	24.2	74	8.48
25–29	131	11.7	129	14.78
30–34	51	4.6	133	15.23
35–39	21	2.6	88	10.08
40–44	11	0.9	19	2.18
45–49	4	0.4	9	1.03
50 and over	8	0.8	1	0.11
Total	1122	100.0	873	100.00

[1] Includes disturbed area burials.

TABLE 2

uping of 1959 assessment of Indian Knoll population by age and sex

ge	Male	Female	?
ars			
der 1	65	75	30
4	50	29	5
9	35	18	1
14	24	28	1
19	26	33	0
24	26	48	0
29	78	50	1
34	77	56	0
39	58	30	0
44	9	10	0
49	9	0	0
and over	0	1	0
al	457	378	38

rials, is 18.56 years. Omitting the in- its, those under one year, the average raised to 22.93 years, again emphasizing high infant mortality. If an Indian oller could survive the first year of life, expectancy would be increased 4.37 ars.

The frequency distribution of the In- n Knoll population is compared to some er populations in figures 2 and 3. Fig- 2 shows a comparison to an Austrian nze Age group and a sample of Egyp- ns from the Roman Period; the figures from Krogman, ('58). The distributions are not similar, Indian Knoll standing apart from the other two curves. This, however, is not surprising when it is noted that these two groups are from cultural levels more technologically and economically advanced, and are indicative of a trend toward greater longevity that has continued to the present day.

Indian Knoll is similar, in terms of population distribution, to the groups shown in figure 3. The same general distribution can be observed in small samples of Neanderthal, Cro-Magnon, and Mesolithic peoples (all from Krogman, '58), and a prehistoric group of Hawaiians (Snow, '60). They can all be observed to have a peak at the 11 year and younger category and in the vicinity of 21–30 years. In three of the 5 examples, the younger class has the larger percentage.

Keeping in mind the average life expectancy at Indian Knoll of 18.56 years, we may examine some other averages, again given by Krogman ('58, p. 246). He finds the average in urban Rome of 2000 years ago to be about 20 years, in 11–13th century England, 35–39 years, in 1900 A.D. in the United States, slightly less than 50 years, and, in many living primitive peoples, "the peak in the curve of death is in the 20's or 30's."

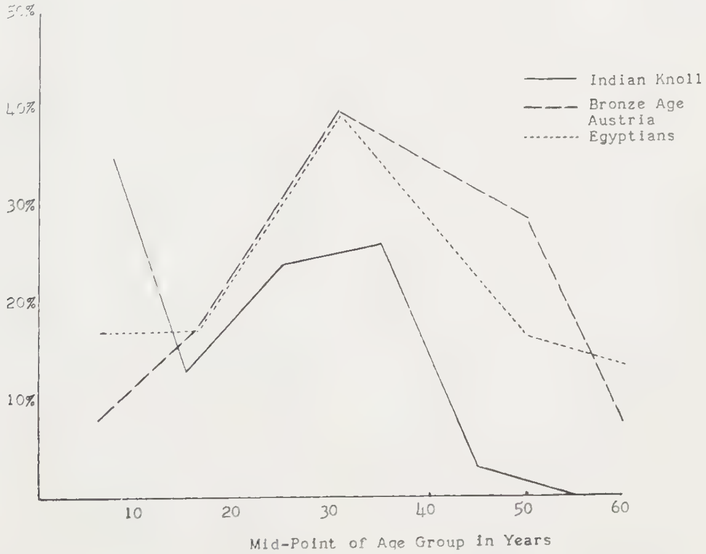


Fig. 2 Indian Knoll compared to more advanced populations.

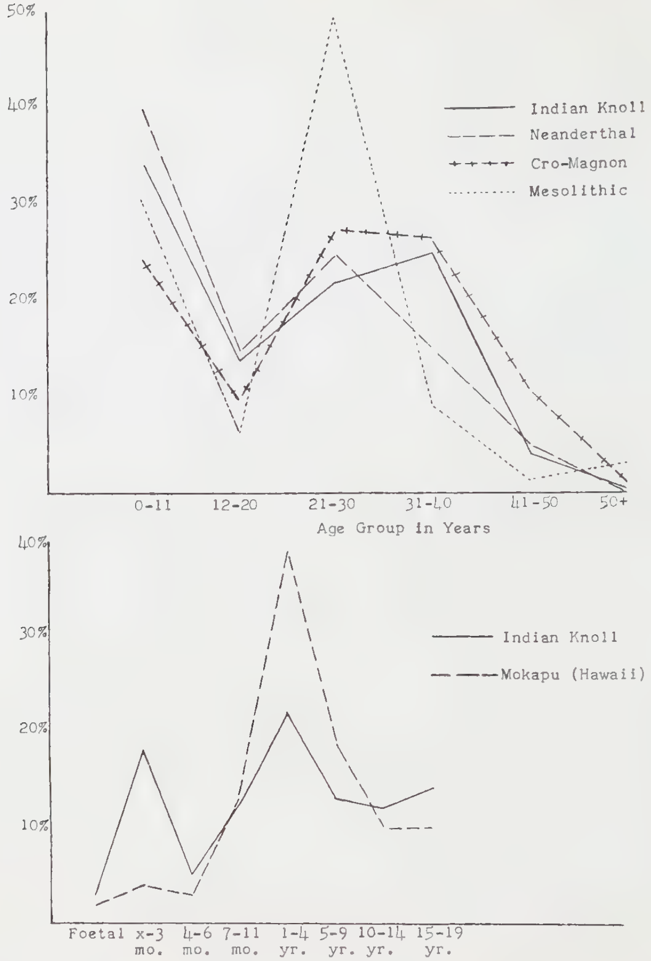


Fig. 3 Indian Knoll compared to more primitive groups.

Methodological aspects

The present study, when compared to the results of the 1941 evaluation, gives a comparison of ages at death of the same skeletal series based, in 1941, on the standards of cranial suture closure of Todd and Lyon ('24 and '25), and, in 1959, on the information gained from the *entire* skeleton.

It is not within the scope of the present paper to summarize the criticisms leveled against the use of cranial suture closure in the aging of skeletal remains. However, recent publications by Cobb ('52), Singer ('53), Brooks ('55) and McKern and Stewart ('57) have all pointed out the variability that exists between individuals in the attainment of closure of these sutur Singer, after observing closure in 4 skulls of various racial affiliations, h concluded that assessment of age bas on these criteria alone ". . . is a hazardo and unreliable procedure" (p. 59). M Kern and Stewart, in addition, fou ranges as high as 21 years among you American males exhibiting similar d grees of suture closure.

In the comparison of the two asse ments of the Indian Knoll series, diff ences were also noted. Figure 4 shows t shift in the frequency distribution betwe the two evaluations.

The average age of the skeletons ov 20 years of age (thus eliminating th

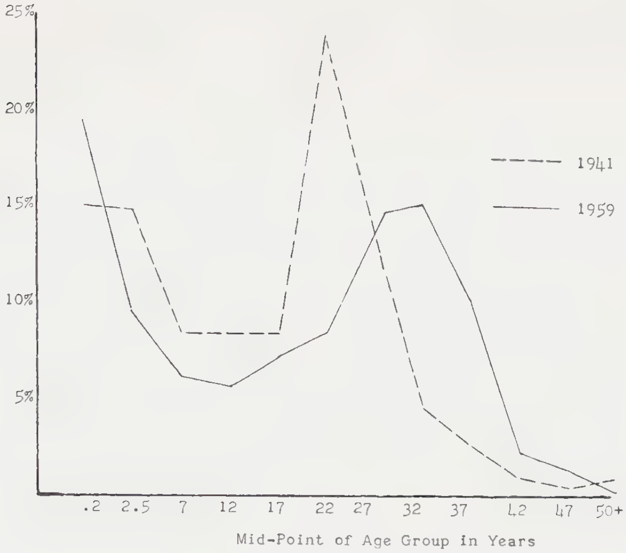


Fig. 4 Distribution of the two assessments.

TABLE 3

Comparison of the two sex assessments of the Indian Knoll series

Assessment	Male	Female	Undetermined
	%	%	%
1941 (Snow)	48.8	40.5	10.7
1959 (Johnston and Snow)	52.3	43.3	4.4

here suture closure was not a factor in
ing) was 26.1 years in 1941 and 30.7
ars in 1959. (Both figures are based only
those skeletons located at the Univer-
ty of Kentucky.) The mean increase, due
differing methodologies of skeletal ag-
g, is therefore 4.6 years. This number
comes significant when it is noted that
cKern and Stewart ('57), in correlating
timated age based on degree of suture
osure with known age, computed a stand-
d error of estimate of 4.4614 years. The
treme closeness of these figures seems
indicate that, on the average, a 4½-year
ror may be expected when aging skeletal
aterial by means of cranial suture
osure.

The sex ratios of the two assessments
e very similar, as shown in table 3. This
dicates that constant results may be ex-
ected when sexing skeletal material, un-
ss a low degree of sexual dimorphism
akes any degree of certainty difficult.

SUMMARY AND CONCLUSIONS

A reassessment of the Indian Knoll skeletal population, in terms of age and sex, and subsequent comparisons, to an earlier assessment, and to other populations, have led to the following conclusions:

1. The demography of the Indian Knoll population is similar to the more primitive, non-agricultural groups, and exhibits little over-all similarity, in terms of age distribution, to more economically and technologically advanced groups.

2. The average difference between skeletal aging by means of closure of the cranial sutures and by means of a composite of skeletal and dental criteria was, at Indian Knoll, 4.6 years. This average is very close to the standard error of estimate of McKern and Stewart ('57) of 4.4614 years, between predicted and actual ages.

3. The sex ratios of the two studies of the same population were similar, indicat-

ing that skeletal sexing, at least as far as Indian Knoll is concerned, gave relatively constant results.

ACKNOWLEDGMENTS

The authors wish to express their appreciation to Dr. Mildred Trotter, Washington University, St. Louis, and to Dr. W. M. Krogman, University of Pennsylvania, for suggestions and criticisms during the preparation of this paper, and to Dr. Herman E. Spivey, former chairman of the Research Fund Committee of the University of Kentucky, whose grant-in-aid made the study possible.

LITERATURE CITED

Brooks, S. T. 1955 Skeletal age at death: the reliability of cranial and pubic age indicators. Am. J. Phys. Anthrop., n.s., *13:* 567–598.

Cobb, W. M. 1952 Skeleton. In: Cowdry's Problem of Aging. Albert W. Lansing, ed. Williams and Wilkins, Baltimore.

Johnston, F. E. 1961 Sequence of epiphyseal union in a prehistoric Kentucky population from Indian Knoll. Human Biology, *33:* 66–81.

Krogman, W. M. 1958 Changing Man. J. Am. Geriat. Soc., *6:* 242–260.

Leigh, R. W. 1925 Dental pathology of Indian tribes of varied environmental conditions. Am. J. Phys. Anthrop., *8:* 179–199.

——— 1928 Dental pathology of aborigina California. Univ. Calif. Publ. in Am. Archaeo Ethnol., *23:* 399–440.

Libby, W. 1955 Radiocarbon Dating, 2nd e University of Chicago Press.

McKern, T. W., and T. D. Stewart 1957 Skele tal Age Changes in Young American Males Technical Report EP-45, Quartermaster Re search and Development Center, Environmen tal Protection Research Division. Natick, Mas sachusetts.

Moore, C. B. 1916 Some Aboriginal Sites o Green River, Kentucky. J. Acad. Nat. Sc Philadelphia, Second series, *16:* part 3.

Neumann, G. K. 1952 Archeology and race i the American Indian. In: Archeology of th Eastern United States. James B. Griffin, ed University of Chicago Press, pp. 13–34.

Reynolds, E. L. 1945 The bony pelvic girdle i early infancy. Am. J. Phys. Anthrop., n.s. 3 321–354.

Singer, R. 1953 Estimation of age from crania suture closure. J. Forensic Med., *1:* 52–59.

Snow, C. E. 1948 Indian Knoll skeletons. Univ Kentucky Rep. in Anthrop., *4:* number 3 part II.

——— 1960 Early Hawaiians on Oahu. In press.

Todd, T. W., and D. W. Lyon, Jr. 1924 Endo cranial Suture Closure. I. Adult males of Whit stock. Am. J. Phys. Anthrop., *7:* 325–384.

——— 1925 Cranial Suture Closure. II. Ecto cranial suture closure in adult males of Whit stock. Ibid., *8:* 23–71.

Webb, W. S. 1946 Indian Knoll. Univ. Ken tucky Rep. in Anthropol. Archaeol., *4:* numbe 3, part I.

A Photographic Method for Craniometrics

T. LEWIN, B. TENGROTH AND B. BERGKVIST
Department of Human Anatomy, University of Gothenburg, Göteborg, Sweden

In order to obtain a complete cranio- gical analysis in anthropological studies ne must use both metrical and graphic chniques. In craniometrics, linear dis- nces are measured between well defined ints on the cranium, usually with com- sses and sliding calipers of different pes. From these measured distances, one calculates ratios or indices which describe the dimensions of the skull. In craniographics, the form of the skull is studied in different planes with the skull fixed in a craniostat. This is usually done by transferring to paper a craniogram or tracing of the skull-contour in the desired plane. The cubic craniophore seems to be

TABLE 1

Mean value of measurements by three craniometric techniques
(All measurements in mm)

Standard craniometric distance as defined by Martin	Sliding calipers	Spreading caliper		Photo technique	
	Mean value of 5 determinations	Mean value of 5 determinations	Deviation from the mean value for the sliding calipers	Mean value of 5 determinations	Deviation from the mean value for the sliding calipers
M 1	181.7	182.6	+0.9	181.9	+0.2
M 3	179.2	180.0	+0.8	179.8	+0.6
M 2	179.5	180.6	+1.1	180.2	+0.7
M 2a	178.0	177.6	−0.4	178.0	±0
M 29	108.6	108.4	−0.2	108.4	−0.2
M 30	125.6	126.2	+0.6	126.4	+0.8
M 31	90.7	91.0	+0.3	91.4	+0.7
M 5	96.1	95.2	−0.9	95.6	−0.5
M 8	142.0	143.2	+1.2	142.8	+0.8
M 9	103.5	104.2	+0.7	103.6	+0.1
M 10	121.9	122.2	+0.3	121.8	−0.1
M 11	125.7	126.4	+0.7	125.8	+0.1
M 12	117.7	116.0	−1.7	118.2	+0.5
M 13	100.0	100.0	±0	100.0	±0
M 17	125.3	126.0	+0.7	126.0	+0.7
M 40	96.0	95.6	−0.4	95.6	−0.4
M 48	73.4	73.8	+0.4	73.6	+0.2
M 43	105.7	106.6	+0.9	105.8	+0.1
M 43	98.3	97.0	−1.3	98.6	+0.3
M 44	96.5	96.0	−0.5	96.4	−0.1
M 45	121.1	118.8	−2.3	122.2	+1.1
M 49	23.0	23.4	+0.4	23.2	+0.7
M 50	25.1	24.8	−0.3	24.8	−0.3
M 46	96.7	98.0	+1.3	96.6	−0.1
M 54	23.6	23.2	−0.4	23.8	+0.2
M 55	55.9	54.6	−1.3	56.2	+0.3
M 51^{s}	39.5	39.2	−0.3	39.4	−0.1
M 51^{d}	40.5	39.8	−0.7	40.4	−0.1
M 62	48.4	47.4	−1.0	49.6	+1.2
M 63	37.9	38.6	+0.7	38.2	+0.3
M 60	56.9	56.0	−0.9	57.4	+0.5
M 61	57.3	58.6	+1.3	58.2	+0.9

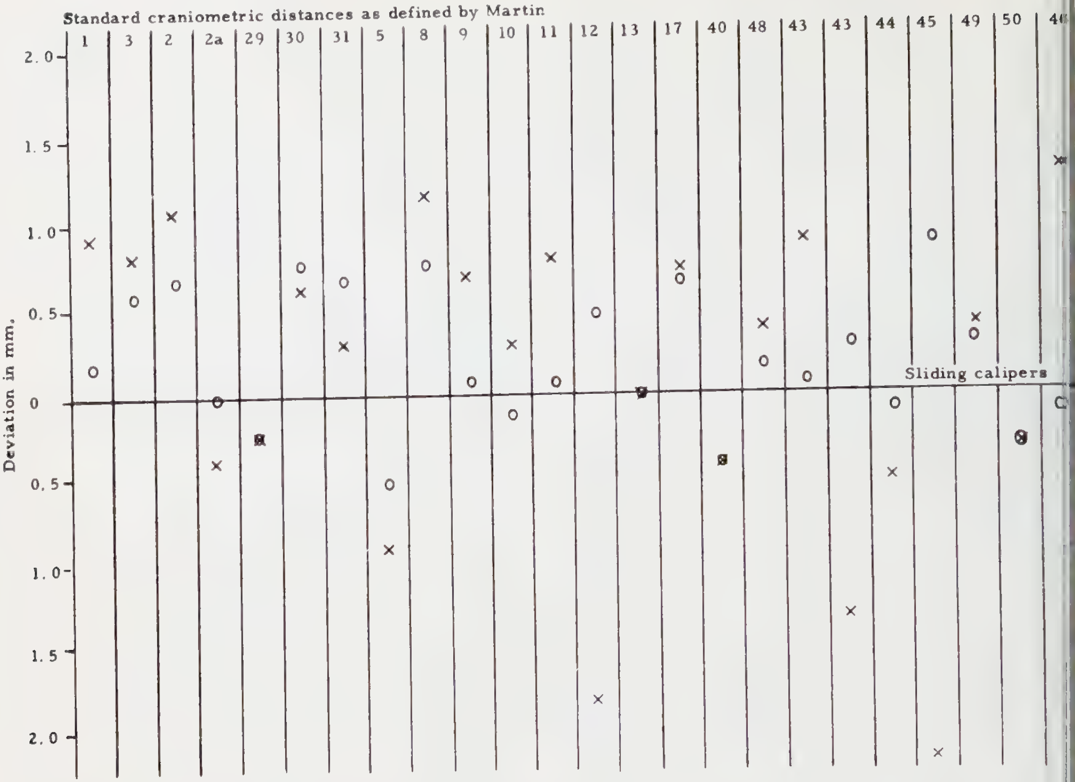


Fig. 1 Large measurements on the cranium and face. The deviation of the spreading caliper (×) and photographic technique (○) from the mean values of the measurements obtained with the sliding calipers.

the most suitable one for this purpose because it is easy to obtain craniograms in frontal, horizontal, and sagittal planes. With these indices and craniograms the skull can be characterized and different skull-types can be compared.

During the last few years, many studies have been made using photographs of the skulls as a craniographic procedure. The photographic technique offers the advantages of speed and convenience and gives a general impression of the skull in its different aspects.

Because of these advantages, Tengroth ('54) modified the photographic technique so that it could be used craniometrically to measure linear distances on medieval skulls.

In this paper the authors have attempted to compare the accuracy and precision of this photographic technique with the earlier craniometric methods.

PROCEDURE

The comparison of techniques was mad by measuring the distances between th standard craniometric points as define by Martin ('57). The measurements wer made 5 times by each method on an adul male medieval skull with sufficient tim intervals so as not to be influenced by th previous measurements. Such measurements are conventionally obtained directl from the skull by means of sliding cal pers and spreading caliper (Tasterzirkel Therefore, these intruments were used fo comparison with the photographic technique.

Measurements were obtained by th photographic technique in the followin way. The location of each craniometri point to be measured was indicated on th skull with plastic pins (figs. 4, 5, 6). Thes are exactly 30 mm long. One end i tapered so that it can be attached accu ately to the craniometric landmark with odeling clay. The blunt end of the pin rojects beyond the contours of the skull nd is colored black so that it can be easily dentified in the photographs. After these ins were applied, the skull was placed in cubic craniophore and oriented with the rankfurt horizontal parallel to the base of he craniophore. Photographs of the skull ere taken in three views, frontal, lateral, nd superior, using a long focal-length ens at a distance of 12.5 meters. A metal od, 485 mm long, was placed on the cranistat parallel to the film plane. The negaves were enlarged so that this rod was 85 mm long in the finished photograph. his provided a life-size picture of the kull on which direct measurements were ade. In such photographs, the craniometric points lie exactly 30 mm proximal o the black mark on the measuring pins. ecause of this relationship it is easy to ocate the craniometric points and to meas- re the distances between them on the hotograph.

RESULTS

The mean values of the measurements btained by these three craniometric techniques is shown in table 1. The standard deviation from these means is less than 0.50 mm in every case and least for the sliding calipers.

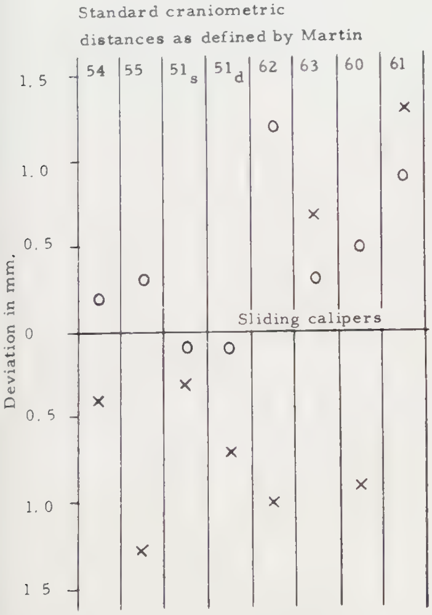


Fig. 2 Small measurements on the face. The eviation of the spreading caliper (×) and the hotographic technique (○).

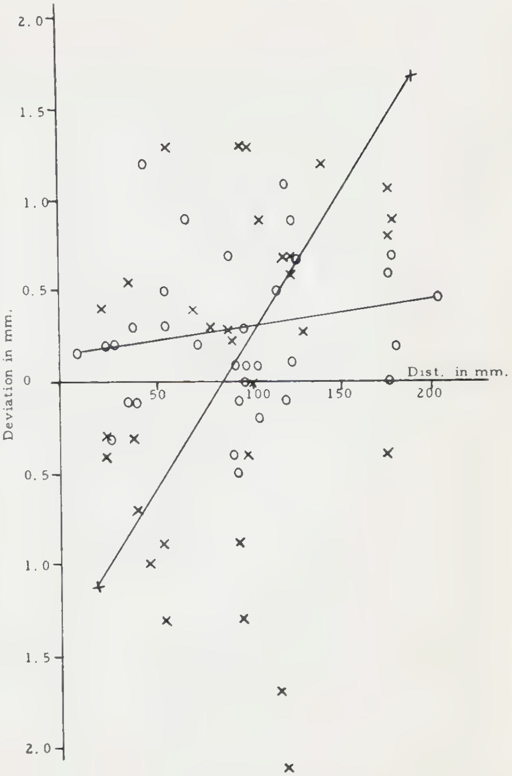


Fig. 3 The relationship between the deviation from the sliding calipers and the distance being measured; ×—×, the spreading caliper; ○—○, the photographic technique.

The distribution of the mean values is shown in figures 1, 2, 3. In these graphs the horizontal base line represents the mean values of the measurements obtained with the sliding calipers which are regarded as the most accurate values. The deviation in millimeters from this value is shown for the spreading caliper (×) and the photographic technique (○). Each point on the graph thus represents the mean value of 5 determinations.

In figure 1, we see the distribution of values obtained from large measurements on the cranium and face. The deviation of the spreading caliper measurements (×), from the base line, is greater than that of the photographic technique (○). For such distances, the photo technique gives a maximum error of less than 1 mm, and the measured value tends to be larger than the actual value.

In figure 2 the distribution of values is shown for small measurements on the face (orbital dimensions, etc.). Here we see that the spreading caliper (×) tends to give values which are too small and the photo technique (○) tends to err in the opposite direction, but its range of error is still smaller than that of the spreading caliper.

In figure 3, the values for all measurements are shown. The deviation from the base line has been plotted against the length of the distance being measured. The trend of error for the spreading caliper (×—×) and the photographic technique (○—○) are indicated. For distances less than 100 mm, the spreading caliper gives values which are too small; above 100 mm, it gives values which are larger than the actual measurement. The photographic technique gives a positive error throughout the whole range of distances, but this error is again shown to be smaller than that of the spreading caliper.

SUMMARY AND CONCLUSIONS

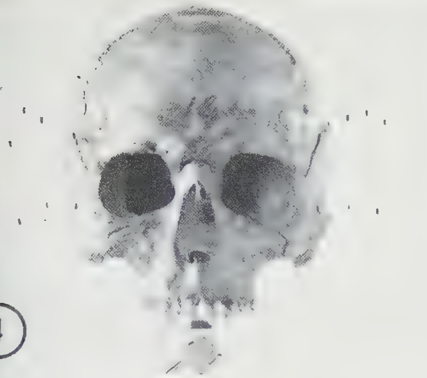
From this study one can conclude that:

1. The photographic technique can be applied to craniometric studies.
2. The photo technique has the advantages of speed and convenience when compared with the sliding calipers and spreading caliper.
3. The photo technique has a smaller range of error than the spreading caliper and it tends to err on the positive side for the full range of distances measured.
4. The spreading caliper tends to err on the negative side for small distances and on the positive side for large distances
5. The photo technique is more accurate than the spreading caliper especially when one is preparing indices based on both large and small distances.

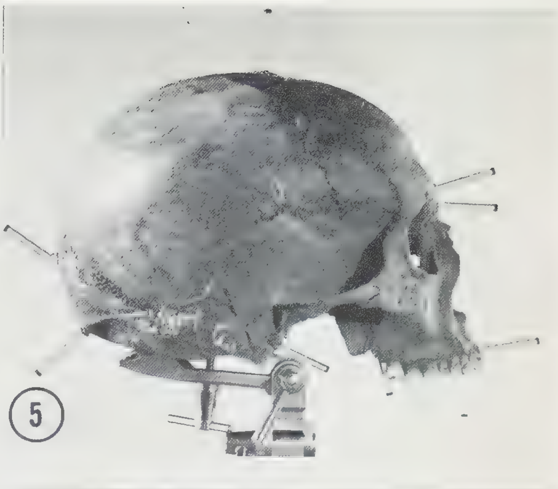
LITERATURE CITED

Martin, R. 1957 Lehrbuch der Anthropologie. G. Fischer Verl., Stuttgart.

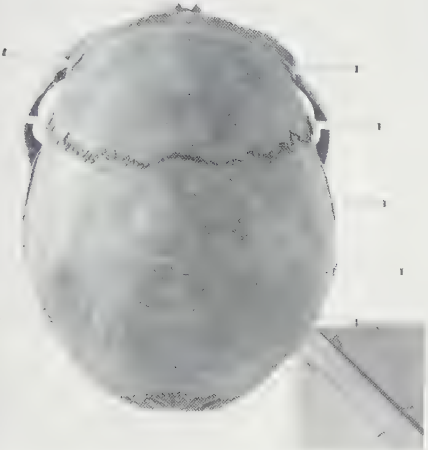
Tengroth, B., and Å. B. Löfgren 1955 Antropologisk och odontologisk undersökning av medeltida skelettmaterial från provutgrävningen av Kongahälla sommaren 1953. Odont Tidsskr., 63: 249–284.



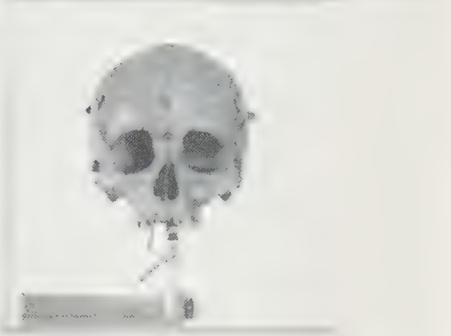
4



5



6



7

4 Skull mounted in cubic craniophore. Frontal view, plastic markers have been attached to the craniometric points, so that the end of the marker projects beyond the contours of the skull.

5 Skull mounted in cubic craniophore, lateral view.

6 Skull mounted in cubic craniophore, superior view.

7 Skull mounted in cubic craniophore, frontal view. A metal rod, 485 mm long, is placed on the craniophore parallel to the film plane.

A Note on the Fusion of the Lunate and Triquetral Centers

RONALD K. WETHERINGTON
Departments of Anthropology and Human Genetics, The University of Michigan, Ann Arbor, Michigan

Recently two publications (Dean and ones, '59; Silverman, '55) have illustrated arious stages in the apparent fusion of he lunate and triquetral bones of the wrist nd have offered plausible explanations s to its cause. Both papers dealt with its ncidence in African children and Silverman showed serial radiograms of a Negro irl from 6 through 8 years of age. Reports of lunate-triquetral fusion indicate t to be more common among Negros than n whites, although no explanation for this as been proposed.

An example of fusion of these carpals was recently found in the course of assess-ng maturation in 1400 hand films of a ontrol group of Hiroshima children, a roject of the Child Health Survey of the Atomic Bomb Casualty Commission.[1] The ingle instance is a Japanese boy of 8½ ears (103 months), in whom the two cen-ers have reached the final stage of fusion fig. 2). So far as we know this is the first report of such fusion in an Oriental. The study is following a cross-sectional, r latitudinal, approach and thus prevents serial radiograms of the stages of fusion. Only left-hand films were taken, making t impossible to ascertain whether the con-ition in this instance is bilateral.

The film clearly illustrates the absence f any line of union of the two centers, as ccurs in Silverman's case ('55; fig. 1C). n none of the illustrations of Dean and ones ('59) is the process of fusion complete, and they suggest that the line of union "may possibly indicate the forma-ion of a pseudo-arthrosis" (p. 280). Completed fusion without a line of union has been reported in white adults (Curr, '46–47; McConnell, '06–'07), and it is not known at what exact age the two centers completed fusion. In the cases of Curr and McConnell the combined centers have reached their final stages of configuration and size; ours is the first case we found in which fusion is completed in a child, while the maturational status of the combined center is still in an early stage. It seems probable, however, that the line of union in Silverman's figure 1C (8 years old) was obliterated shortly thereafter, at about the same age as ours or slightly later.

Dean and Jones also note a tendency of the triquetral to elongate in their cases of "fusion" and suggest a relationship between elongation and the tendency to fuse with the lunate. In our case fusion is so complete that it is difficult to find the original borders. However, we have found several instances in which the triquetral was elongated and rather narrow with no evidence of the tendency of fusion. It seems likely, however, that as the ossification centers approach each other both will tend to lengthen beyond normal dimensions.

Figure 1 illustrates what we consider to be the possible stages of fusion in our case, with the stippled area representing the zone of chondrification prior to ossification. It seems unlikely that accessory centers between the two normal centers could be responsible for this particular case. We found many such accessory centers in our study without any suggestion of fusion. It likewise seems probable that the area between the two centers is joined by a cartilaginous mass sometime prior to overlapping or joining of ossification, but

---

[1] We gratefully acknowledge the financial support in this survey of the U. S. Atomic Energy Commission, the Rockefeller Foundation, the U. S. Public Health Service, and the Association for the Aid of Crippled Children. Gratitude is expressed to Dr. J. V. Neel and D. J. N. Spuhler for their guidance.

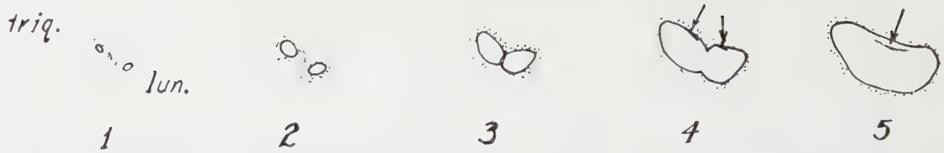


Fig. 1 Possible stages of fusion of the lunate and triquetral seen in figure 2. Stippled areas represent zones of chondrification. Arrows indicate volar markings.

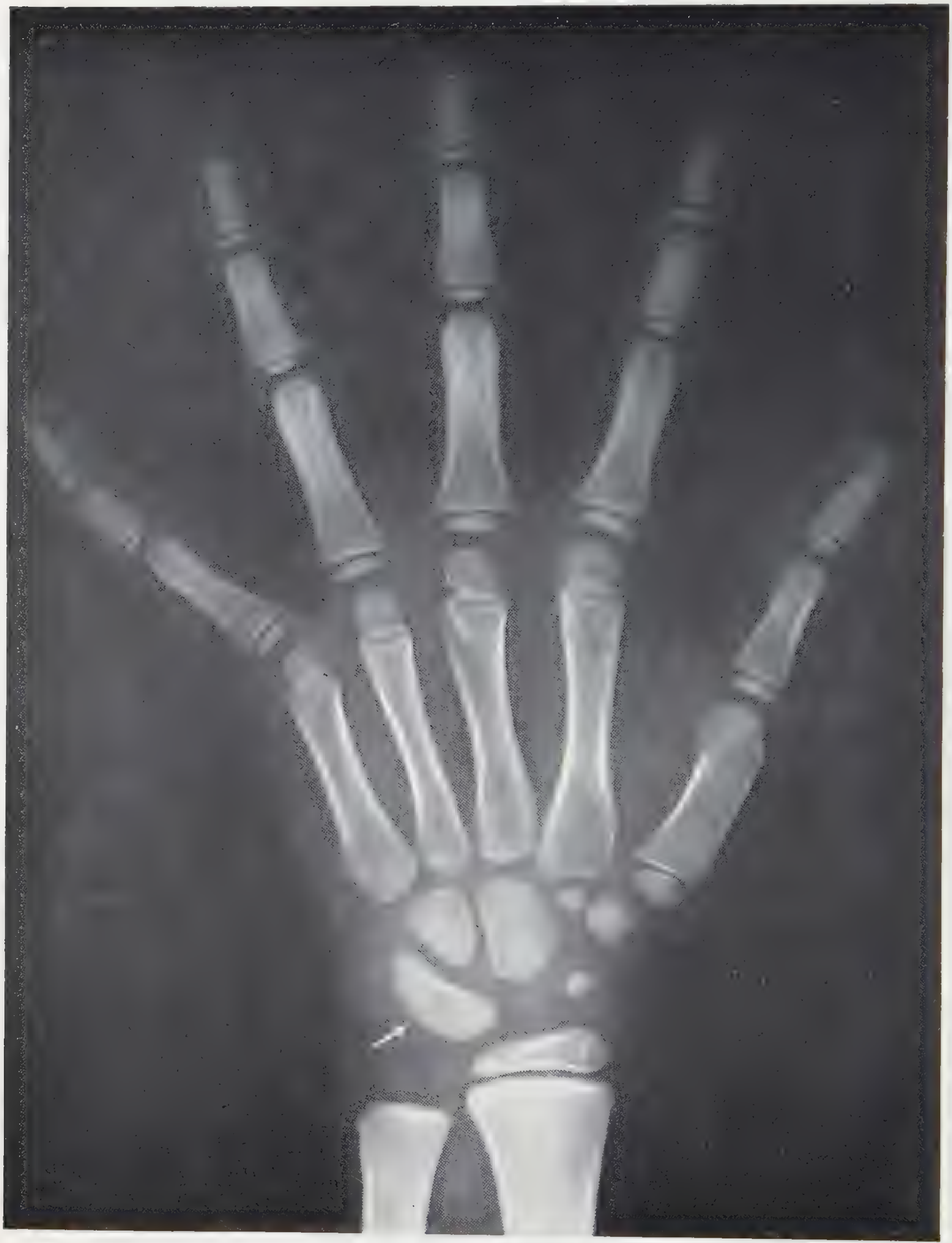


Fig. 2 Fusion of lunate and triquetral centers in Japanese (Hiroshima) boy, aged 103 months. (Courtesy Atomic Bomb Casualty Commission).

hether this "transarticular" chondrifica- on arises in the fetal stage or after birth a moot question. We prefer to think at the two cartilaginous masses join just ter the two centers of ossification have peared, or shortly before, as illustrated. wo centers arising in one mass of carti- ge is, of course, common, for we see it ulnar and phalangeal epiphyses, but hen this occurs the two centers invari- ly join to form a single ossific center rly in development. In the case of nate-triquetral fusion, however, the two nters are usually well-developed and ten have advanced volar surfaces before ining.

A rudimentary volar marking appears our film as a dense area on the hamate argin. It is possible that before fusion e two centers were beginning to de- lop separate articular markings (fig. 1, age 4).

The hand film shown (fig. 2) was graded our CHS Method (Wetherington, '61), ilizing maturity points obtained from the dicators of maturity in Greulich and yle's *Atlas* ('59). By this method the hild was found to be slightly retarded in eletal development (90% of normal) for s age, though not significantly so. Nor- al children in his age group have attained Total Maturity Index of 50% (of com- eted maturity), whereas his Index was 5%. We do not believe this slight re- rdation to have any association with the nate-triquetral fusion.

SUMMARY

The fusion of lunate and triquetral carpal centers in the wrist of a Japanese boy of 8½ years was examined. Fusion of the centers was complete and no line of union remained.

It is suggested that the union of the two zones of chondrification preceded the union of the centers and that the centers thus developed, shortly after ossification began, in a single mass of cartilage.

The other centers of the hand had attained a maturational status just below normal, but it is believed that the fusion of the two centers has no effect on the development of the rest of the hand.

LITERATURE CITED

Curr, J. F. 1946–1947 Congenital fusion of lunate and triquetrum. Brit. J. Surg., *34:* 99–100.

Dean, R. F. A., and P. R. M. Jones 1959 Fusion of triquetral and lunate bones shown in serial radiographs. Am. J. Phys. Anthrop., *17:* 279–288.

Greulich, W. W., and S. I. Pyle 1959 Radiographic Atlas of Skeletal Development of the Hand and Wrist. Stanford University Press, California, 2nd ed.

McConnell, A. A. 1906–1907 A case of fusion of the semilunar and cuneiform bones. J. Anat. Physiol., *41:* 302–303.

Silverman, F. N. 1955 A note on the os lunatotriquetrum. Am. J. Phys. Anthrop., *13:* 143–145.

Wetherington, R. K. 1961 An alternate method of assessing skeletal maturity from the hand and wrist. Papers, Mich. Acad. Sci., Arts, and Letters (1960 meeting), *46:* 419–433.

he Blood Group Antigens in Goajiro Indians

M. LAYRISSE, Z. LAYRISSE AND J. WILBERT
Instituto Venezolano de Investigaciones Cientificas,
Centro de Investigaciones del Banco Municipal de Sangre del D. F. and
Fundación La Salle de Ciencias Naturales, Caracas, Venezuela

The Goajiro occupy the arid La Goajira eninsula which at 11°N and 73°W ex- nds into the Caribbean Sea and which olitically belongs to Colombia except for narrow coastal belt to the south which a part of Venezuela. The Indians have een reported in that area since early his- ric times and with a population of some 0,000 individuals, they represent one of e most numerous modern Indian tribes South America.

Regarding Goajiro culture identification, e are inclined to believe these Indians to ave been in possession of a Marginal type culture at the time of the Discovery. he other possibility would be to ascribe them a lower type of Tropical Forest lture, featuring incipient agriculture, eaving, pottery, village communities ased on kinship, and a religion limited shamanism and beliefs in mythological lestial beings and bush spirits. It is dif- cult to decide in favor of any one of these ternatives, since only scarce traces of e-Colombian Goajiro remain. It seems fe to say that the Goajiro did not share e higher level of culture development served in the other Arawakan tribes of enezuela and the Guianas. In the past, thropologists may have conceived of a iform culture type as being standard for l Arawakan-speaking Indians. This does t seem to accord with the facts and, deed, on a previous occasion, we had to scribe the culture of the Paraujano, the rawakan neighbors of the Goajiro, as ing Marginal in type (Wilbert, '59). owadays, many of the characteristic fea- res of Tropical Forest cultures have a ry restricted distribution among Goajiro, d are of subordinate importance. Clos- g the vicious circle of such argumenta- on again, we have to admit that many ements of Goajiro culture may very well interpreted as genuine relics of an early Marginal Goajiro culture which only lost importance because of changes in the traditional economic pattern. By 1550, the latter suffered a powerful shock, through the adoption of cattle, horses, sheep, goats, pigs, fowl, and donkeys, introducing a series of changes with far-reaching consequences.

As expected, these radical changes in the Goajiro traditional economy also affected their social structure. According to several authors, Goajiro society is composed of some 30 matrilineal sibs, named after animals. Today, the majority of these still exist, but herding has made them nomadic and non-localized, although large sib-territories are respected. Houses which may have been more solid structures once, were replaced by simple shelters. Status differences between the sibs increased considerably ever since cattle became the basis for the same. While the authority of the local group rested strongly on the personality of mother's brother, property was, and thoretically still is, owned communally. A process of individualization favors personal property and personal status, and the breaking up of larger bands into extended families and nuclear families appears to be inevitable. The latter stage of development has not been completely reached, mainly because herding requires the cooperation of a number of persons who are conveniently supplied by the extended family.

Today, most of the Goajiro sibs still have a chief whose office is matrilineally inherited but there is no central government. The social structure of the Goajiro is characterized by extended families with polygynous nuclear family households. The most important dividing line going through inter- or extra-group relations is the distinction the Goajiro make between "blood-relatives" and "flesh-relatives." Blood-relatives are patrilineally related, whereas flesh-relatives are related to Ego through the mother's line. Kinship ties between flesh-relatives are considered to be stronger than those existing between blood relatives. Among all kinsmen the maternal uncle possesses the greatest authority and his word counts in all domestic affairs. Therefore we find the extended family clustered around the homestead of the maternal uncle, which makes the Goajiro a matrilineal avunculocal society; otherwise residence is matrilocal. The kinship system of the Goajiro is of the Crow type. As for the sanctioned forms of cousin marriage, Ego may marry any cousin on either side except for mother's sister's children. Ego may also marry any kinsman of the third degree with the exception of a mother's sister's daughter's child. All relatives of the 4th degree are potential spouses. Polygyny is practiced and is definitely a mark of status and rank. Sororate is sanctioned, although it very rarely occurs. The data indicate a very typical Crow system (Jahn, '27; Steward-Faron, '59; Wilbert, '58).

Blood group antigen studies

The blood groups of the Goajiro were first examined by Layrisse, Arends and Domínguez Sisco in 1955. The authors tested 152 Goajiro of Siruma (Venezuela) for the ABO, Rho, and Di^a antigens, finding 98% of group O, 99% of Rho positive and 5.26% of Di(a+). In 1957, Núñez Montiel, Arteaga, and Núñez Montiel examined 370 Goajiro Indians settled at Siruma and Las Tabaras, near Maracaibo. All the samples examined were group O, Rho positive and 118 samples were tested for the antigens C,c,D,E, and e. They found 9.22% of the chromosome R_0, 61.07% of the R_1, and 28.71% of the R_2.

In December, 1958 the authors of the present paper carried out an expedition with the purpose of testing some more Venezuelan Goajiro. On this occasion, 119 blood samples were taken from individuals not too closely related and who belonged to different sibs distributed throughout an intensive area. The following antibodies were used for the blood group tests:

1. Anti-A, anti-A_1, and anti-B for A_1A_2BO.
2. Anti-M, anti-N, anti-S, anti-s, an anti-U for MNSs.
3. Anti-P_1 (previously called anti-P and anti-$P+P_1$ (previously called anti-T (Sanger, '55).
4. Anti-C, anti-c, anti-D, anti-E, anti- and anti-V for Rh.
5. Anti-Lu^a for Lutheran.
6. Anti-K and anti-k for Kell.
7. Anti-Le^a for Lewis.
8. Anti-Fy^a for Duffy.
9. Anti-Jk^a for Kidd.
10. Anti-Di^a for Diego.
11. Anti-Js^a for Js.

A_1A_2BO. Only 5 samples were distin from group O indicating a small admi ture with either Caucasoids or Negroid

MNSs. The gene *M* occurred in hig frequency as in most Indian tribes teste The gene *S* was also high (44.71%) whic is very similar to the incidence found i Paraujano (Layrisse, Layrisse and Wilber '59a), Carib (Layrisse, Layrisse and Wi bert, '59b), and Caingang (Fernánde Junqueira, Kalmust, Ottensooser, Pasqua lin and Wishart, '58). This gene wa mostly traveling with the gene M in ratio of 3/1.

P. According to previous studies o American Indian blood, including th present data, it seems that the low fr quency of the gene P_1 (previously calle P) is a genetic characteristic of the Ame ican Indian which if so, would permit th separation of Indians from Negroes an Whites.

Rh. The presence, although low, o the chromosome $R_0(cDe)$ (3.68%) as we as that of the V antigen indicate Negro a mixture. The chromosomes $R_1(CDe)$ an $R_2(cDE)$ ratio (4/1) was within the limi that had been observed in other Sout American Indians although different fro the ratio found in North American I dians. All cases were Rho(D) positive.

Lutheran, Kell and Lewis. Only on K(+) was found but not a single samp carried either the Lu^a or the Le^a antigen

Duffy and Kidd. The incidences of th gene *Fy^a* (67%) and *Jk^a* (59%) were ve similar to those obtained in Paraujan (Layrisse, Layrisse and Wilbert, '59a) an Carib tribes (Layrisse, Layrisse and W bert, '59b).

Diego. The frequency of the Di(a+) this tribe (10%) is the same as oberved in Paraujano.

Js. The Js^a antigen was only present one sample, which is in accordance ith the frequencies of the chromosome $_0$ and the gene *V*.

Rate of admixture

Although the social control pattern of e Goajiro is a strong barrier which preents interbreeding with other populations, e vicinity of settlements occupied by hite and Negro in the southern part of a Goajira provides the possibility that ey may have certain admixture with oth ethnic groups.

Negro admixture. For the estimation the rate of gene flow introduced into the oajiro population we have used the freency of Negroid genes *V*— and *Js*^{a} found the samples presented here. It was not ossible to measure accurately the R_0 freency. In the Rh chromosome calculaon, a value for cDe + cde = 1— (C + E) CDE = 3.49% was found. Since this ibe has also White admixture it would be ry difficult to ascribe which fraction of e total amount could correspond to each romosome.

According to Glass and Li's formula the te of Negro admixture, using the gene would be 1.91%, and using the gene ^{a} it would be 3.44% (table 1); then the erage of admixture accumulated after 0 years would be 2.67%. This figure ould be taken as approximate because of e small number of samples tested.

White admixture. The most probable idence of White admixture in the Gao tested was the presence of a sample +). While this antigen was reported be present at a rate of about 10% in ucasoids, it proved to be 1% or less in est African Negroes and negative in the ajority of the American Indian tribes studied. According to the frequency of this gene in the Goajiro, the Caucasoid genes introduced by the descendants of Spaniards would be about 8.19%.

If we try to estimate the Caucasoid admixture using the genes *A* and *B* it would be necessary to subtract first the genes responsible for the Negro admixture and later calculate the rate of White admixture. The available data for West African Negroes (Mourant, Kopec and Domaniewska, '58) show a frequency of 14.97% for the gene A, 12.70% for the gene B and 72.57% for the gene O; so that 2.67% of these frequencies come up to 0.39% for A and 0.33% for B.

Since the Goajiro showed a frequency of 1.28% of A and 0.85% of B there remained 0.89% of A and 0.52% of B after the genes responsible for the Negro admixture were subtracted. According to Mourant, Kopec and Domaniewska ('58), the frequency of A in Spaniards is 28.24% and of B is 6.24%. The calculation of Spanish admixture from the remaining frequency of A and B in the Goajiro would be 3.12% according to the gene A and 8.33% according to B. Therefore the average of Spanish admixture calculated by the genes A, B and K amounts to 6.54%.

This indicates then, that in spite of their having been in contact with White-Negro populations in Venezuela and Colombia for approximately three centuries, the Goajiro remain practically unmixed. Since we tested a small number of samples and the White-Negro admixture is rather low, the figures for Negro admixture (2.67%) and White admixture (6.54%) should be considered as approximate.

Table 2 shows the probable distribution of blood groups in prehistoric Goajiro. It was calculated by subtracting in each blood group system the genes responsible for White-Negro admixture and by ele-

TABLE 1

Rate of West African Negro found in the Goajiro Indians according to Glass and Li's formula

Genes or chromosomes	Q	q_o	q_x	Percentage of admixture accumulated
V	22.54	0.00	0.43	1.91
Js^a	12.50	0.00	0.43	3.44

TABLE 2

Frequency of blood group antigens in Goajiro Indians

	Modern Goajiro				Prehistoric Goajiro possible frequency	
	Phenotypes (%)			Genes or chromosomes	Phenotypes	Genes or chromosomes
	Number observed	Frequency observed	Frequency expected			
				%	%	%
A_1A_2BO System						
A_1	3	2.52	2.52	1.28	0.00	0.00
B	2	1.68	1.67	0.85	0.00	0.00
O	114	95.79	95.79	97.87	100.00	100.00
Total	119	99.99	100.00	100.00	100.00	100.00
MNSs System						
MMSS	18	15.13	15.58	MS 39.47	16.92	40.93
MMSs	27	22.69	25.32		24.05	
MMss	17	14.28	10.21	Ms 31.96	10.04	31.52
MNSS	10	8.40	3.34		3.36	
MNSs	18	15.13	21.83		21.98	
MNss	18	15.13	15.55	NS 4.24	15.96	4.08
NNSS	0	0.00	0.18		0.18	
NNSs	3	2.52	2.06	Ns 24.33	1.93	23.47
NNss	8	6.72	5.92		5.57	
Total	119	100.00	99.99	100.00	99.99	100.00
All samples were U(+); $\chi^2 = 12.02$; n = 8; $0.20 > P > 0.10$.						
P System						
P_1	63	52.94		31.41	49.43	28.89
P_2	56	47.05		68.59	50.57	71.11
p	0	0.00		0.00	0.00	0.00
Total	119	100.00		100.00	100.00	100.00
Rh System						
CCDEE	0	0.00	0.02	CDE 1.34	0.02	1.46
CCDEe	2	1.68	2.08		2.35	
CCDee	58	48.74	60.25	CDe 77.62	65.09	80.68
CcDEE	1	0.84	0.46		0.52	
CcDEe	40	33.62	27.04		28.83	
CcDEeV	1	0.84				
CcDee	11	9.24	5.72	cDE 17.36	0.00	17.86
ccDEE	4	3.36	3.01		3.19	
ccDEe	1	0.84	1.28		0.00	
ccDee	1	0.84	0.14	cDe 3.68 cde		0.00
Total	119	100.00	100.00	100.00	100.00	100.00
$\chi^2 = 6.53$; n = 4; $0.05 > P > 0.02$.						

TABLE 2 (*Continued*)
Frequency of blood group antigens in Goajiro Indians

	Modern Goajiro				Prehistoric Goajiro possible frequency	
	Phenotypes (%)					
	Number observed	Frequency observed	Frequency expected	Genes or chromosomes	Phenotypes	Genes or chromosomes
				%	%	%
			Lutheran System			
Lu(a+)	0	0.00	0.00	Lu^a 0.00	0.00	0.00
Lu(a−)	119	100.00		Lu^b 100.00	100.00	100.00
			Kell System			
KK	0	0.00	0.00	K 0.43	0.00	0.00
Kk	1	0.84	0.85		0.00	
kk	118	99.16	99.14	k 99.57	100.00	100.00
			Lewis System			
Le(a+)	0	0.00			0.00	
Le(a−)	119	100.00			100.00	
			Duffy System			
Fy(a+)	106	89.07		Fy^a 66.96	91.96	70.43
Fy(a−)	13	10.93		Fy^b Fy 33.04	8.74	29.57
			Kidd System			
Jk(a+)	99	83.19		Jk^a 59.02	83.13	58.92
Jk(a−)	20	16.81		Jk^b 40.98	16.87	41.08
			Diego System			
Di(a+)	12	10.08		Di^a 5.18	10.98	5.65
Di(a−)	107	89.92		Di 94.82	89.02	94.35
Total	119	100.00		100.00	100.00	100.00
			Js System			
Js(a+)	1	0.84		Js^a 0.43	0.00	0.00
Js(a−)	118	99.16		Js 99.57	100.00	100.00
Total	119	100.00		100.00	100.00	100.00

[1] For the calculation of the χ^2 the Rh phenotypes were grouped as follows: 1 (CCDEE-CCDEe), 2 (CCDee), 3 (CcDEE-1CcDEe), 4 (ccDEE) and 5 (CcDee-ccDEe-ccDee).

ting the remainder from 90.79% to 00%. It can be expressed by the formula:

$$X = \frac{a - (B \cdot b) - (C \cdot c)}{1 - B - C}$$

here X would be the gene frequency in ehistoric Goajiro; a is the gene frequency modern Goajiro; B the rate of Spanish lmixture; b the gene frequency in Spanh; C the rate of West African Negro adixture; c the gene frequency in West frican Negroes.

DISCUSSION

Together with the Cariban-speaking Inans, the Arawakan belonged to the two incipal groups of Indians in the Guianas d in lowland Venezuela. Although rly maps and sources mention a larger number of Arawakan-speaking tribes in the area which to-day belongs to Venezuela, their number is extremely reduced. The only representatives of the Arawakan family which still exist in Venezuela in aboriginal communities are: the *Goajiro* and *Paraujano* in Western Venezuela (Estado Zulia), the *Aruaco* in the extreme East of the country (Territorio Federal Delta Amacuro), and the *Baré-Baniva-Mandahuaca* to the South (Territorio Federal Amazonas), (Dupouy, '53). None of these tribes has ever been thoroughly studied and blood group tests are available only of the first two tribes mentioned (Layrisse, Layrisse and Wilbert, '60a).

It is noteworthy that the rate of White-Negro admixture among the Goajiro showed such a low rate, in spite of early and relatively extensive contacts between the Old and the New World. It certainly proves the pattern of social control on a sib basis typical for the tribe under discussion, to have been a very effective barrier of gene flow and that recent observations of cooperation among local groups in repelling invaders, may represent an institution of long standing. Had we tested certain peripheral Goajiro groups, we are certain to have had established a considerably higher rate of admixture, since the process of individualization of the person as well as of the family can be observed there to be in full swing, favoring the break-down of the original boundaries of gene flow between the Goajiro and the White-Negro intruders. If we were to point out the basic cause of th process, it would not be mistaken to ref to the changes in the traditional econom pattern as being the responsible maj stimuli.

In the evaluation of the available bloo groups data we have also attempted genetic comparison between the Goaji and Paraujano. This has met with co siderable difficulties since the modern re resentatives of both tribes carry a ce tain amount of Negro and White gen which is apt to disturb the phenotyp frequencies. It was considered to be mo practical, therefore, to establish a co parison between the probable phenotyp frequencies of the prehistoric Goajiro an Paraujano, deductable from the inciden

TABLE 3

Comparison of the MNSs, P, Rh, Duffy, Kidd and Diego phenotypes between the Goajiro and Paraujano tribes

Pattern of calculation—comparison of the MNSs phenotypes between the modern Goajiro and Paraujano

	Absolute number					χ^2 $\frac{(\text{Obs.}-\text{Exp.})^2}{\text{Exp.}}$	
	Observed		Total	Expected			
	Goajiro	Paraujano		Goajiro	Paraujano	Goajiro	Paraujano
			MNSs System				
MMSS	18	11	29	14.44	14.56	0.88	0.87
MMSs	27	29	56	27.88	28.12	0.03	0.03
MMss	17	6	23	11.45	11.54	2.69	2.67
MNSS	10	5	15	7.47	7.53	0.85	0.85
MNSs	18	37	55	27.38	27.62	3.21	3.19
MNss	18	11	29	14.44	14.56	0.88	0.87
NNSS	0	2	2	1.00	1.00	1.00	1.00
NNSs	3	10	13	6.47	6.53	1.86	1.84
NNss	8	9	17	8.46	8.54	0.02	0.02
Total	119	120	239	118.99	120.00	22.76 $n = 8$; $0.01 > P > 0.001$.	

Blood system	Comparison between the modern Goajiro and Paraujano			Comparison between the prehistoric Goajiro and Paraujano[1]		
	χ^2	Number	Probability greater than:	χ^2	Number	Probability greater than:
MN	5.99	2	0.05	3.38	2	0.10
Ss	12.68	2	0.001	4.36	2	0.10
MNSs	22.76	8	0.001	15.02	8	0.05
P	0.28	1	0.50	6.79	1	0.001
Rh[2]	16.71	4	0.001	2.00	3	0.50
Duffy	0.38	1	0.50	0.94	1	0.30
Kidd	0.14	1	0.70	0.12	1	0.70
Diego	0.75	1	0.30	2.24	1	0.10

[1] The same number of modern Goajiro and Paraujano tested was taken for the calculation of the prehistoric tribes.

[2] See footnote 1, table 2.

the modern representatives of these ibes.

Table 3 shows the values of χ^2 and P btained by comparing the MNSs, P, Rh, uffy, Kidd and Diego phenotypes of the odern Goajiro and Paraujano as well as y a comparison of the probable phenoypes in the prehistoric ancestors of these ibes.

The results of χ^2 on P, Duffy, Kidd and iego in the modern Goajiro and Parauano give a probability greater than 1 in 3 at the deviation of the phenotype freuencies is due to chance; but the probaility with the MNSs and Rh is less than in 100 indicating that a real genetic difrence exists between the two modern ibes.

The frequency of probable phenotypes prehistoric Goajiro and Paraujano fits uch better since with the exception of , the blood groups gave a probability eater than 1 in 20 indicating that there ctually did not exist any real difference etween the phenotypes of the two tribes.

For the Diego system, the Goajiro pheotypes were estimated by summing up e phenotypes of the Siruma settlement udied by Layrisse, Arends and Domínez Sisco ('55) as well as of those of the oajiro presented here. The incidences both modern and prehistoric Goajiro d Paraujano were very close giving a obability greater than 1 in 10. This enetic relationship between two tribes of entical linguistical affiliation, confirms ce again the observation we arrived at a more comprehensive study of the Di^a tigen recently published (Layrisse and ilbert, '60). We refer to the thesis that henever two or more tribes can be proved speak dialects of the same motherngue, the percentage of frequencies of e Diego antigen within such populations nds to be in the same range.

Up to the present we have evidence only r a number of representatives of the ariban, Chibchan, Algonkian, Athapasaan, Eskioman linguistic families. The ct that independently, Livingstone ('58) rived at the same conclusions in a simir study on African aborigines, seems to bstantiate the theory. In any case, we elieve that the phenomenon appears to be anything but surprising, since the fact that two tribes speak demonstrably related languages, has always been accepted as the most indubitable evidence of past historical connections. The reason why we hesitated to think along these lines, must have rooted in the phobia anthropologists habitually exhibit when cultural and genetic data are to be correlated. Our data are not utilized to prove one another; rather it is only proposed that the results of parallel executed studies on the genetics and the linguistics of a number of tribes, could result in a fruitful collaboration in identifying tribes and societies. The fact that by this method time depth could be attached to genetic research, by means of glottochronology, is clearly a very useful by-product of the proposed procedure. Among other insights, it may yield valuable information on questions such as direction of gene flow, relative stability of a gene pool, ethnic identity of two groups which at the time of investigation speak the same languages as a result of acculturation, and so on.

SUMMARY

The number of 119 blood samples from Goajiro Indians of Venezuela were tested for the blood group systems A_1A_2BO, MNSs, P, Rh, Lutheran, Kell, Lewis, Duffy, Kidd, Diego and Js. According to the frequency of genes A_1, A_2, B, V, K and Js^a it was roughly possible to determine that these Indians have an admixture of about 2.67 % of Negroes from West Africa, and 6.54% of White represented by Spaniards. The blood group frequencies were generally in accordance with those expected in South American Indians. The Di^a incidence was very close to that found in Paraujano, the Arawakan neighors of the Goajiro.

ACKNOWLEDGMENT

This work was supported in part by a grant from the Fundación Creole, Caracas. We wish to thank Misses Iris Dugarte, Adelina Ojeda, Norma Matute and Anna Jancew, for their technical assistance. We are also indebted to Drs. Guzmán García Martín, Bartolomé Zunimo (Zona XV Malariología, Maracaibo) and Dr. Alonzo

Núñez Montiel, Misses Rosa Matilde Hernández, Carmen Juárez (Banco de Sangre de Maracaibo) for their collaboration in the collection of blood samples.

We are greatly indebted to Dr. Eloise Giblett (King County Central Blood Bank, Seattle, Washington), A. E. Mourant (The Lister Institute, London), Kurt Stern (Blood Center, Mount Sinai Medical Research Foundation, Chicago), R. T. Simmons (Commonwealth Serum Laboratories, Victoria, Australia), Philip Levine (Ortho Research Foundation, Raritan, New Jersey), J. P. O'Riordan (The National Blood Transfusion Association, Dublin), M. Shapiro (The South African Blood Transfusion Service, Johannesburg), and T. J. Greenwalt (Junior League Blood Center, Milwaukee) for supplying us with critical anti-sera.

LITERATURE CITED

Dupouy, W. 1953 El Indio en el mapa de Venezuela. Tierra Firme, *2:* 15–18.

Fernández, J. L., P. C. Junqueira, H. Kalmus, F. Ottensooser, R. Pasqualin and P. Wishart 1957 P.T.C. thresholds, colour vision and blood factors of Brazilian Indians, Kaingang. Am. J. Human Genet., *22:* 15–22.

Glass, B., and B. B. Li 1953 The dynamics racial intermixture and analyses based on t American Negro. Ibid., *5:* 1–20.

Jahn, A. 1927 Los aborígenes del Occide de Venezuela, Caracas.

Layrisse, M., T. Arends and R. Domínguez Sis 1955 Nuevo Grupo Sanguíneo encontrado descendientes de Indios. Acta Med. Venez., 132–138.

Layrisse, M., Z. Layrisse and J. Wilbert 196 Blood group antigens among the Parauja Am. J. Phys. Anthrop., *18:* 131–140.

Layrisse, M., Z. Layrisse and J. Wilbert 196 Blood group antigen tests of the Yupa India American Anthropologist, 62, *3:* 418–436.

Layrisse, M., and J. Wilbert 1960 El Antíge del Grupo Sanguíneo Diego (Di^{a}). Editor Sucre, Caracas.

Livingstone, F. B. 1958 Anthropological i plications of Sickle cell gene distribution West Africa. Am. Anthrop., *60:* 533–562.

Mourant, A. E., A. C. Kopec and K. Domaniews 1958 The ABO Blood Groups. Blackwell S entific Publications, Oxford.

Núñez Montiel, J. T., R. Arteaga Pérez and Núñez Montiel 1957 Estudio hematológ en grupos indígenas del Estado Zulia. Siste ABO, MN, Rh, Duffy y Kell. Acta Cient. Vene *8:* 10–13.

Steward-Faron 1959 Native Peoples of Sou America. New York.

Wilbert, J. 1958 Kinship and social organi tion of the Yecuána and Goajiro. Southw. Anthrop., *14:* 51.

——— 1959 Zur Soziologie der Parauja Z. Ethnologie, *84:* 81–87.

Size and Form of the Dental Arches in Children with Good Occlusion Studied Longitudinally from Age 9 Years to Late Adolescence[1]

VIRGINIA B. KNOTT
Iowa Child Welfare Research Station, Iowa City, Iowa

This report presents findings on age hanges in the size and form of the maxil- ry and mandibular dental arches. Al- hough many research papers have been ublished on this topic, few are based on rictly longitudinal material (Cohen, '40; peck, '50; Woods, '50; Brown and Dau- aard-Jensen, '51; Barrow and White, '52; llman, '51 and '56). To the fund of nowledge obtained through these investi- ations, the present study contributes a umber of results from analyzing data on 9 white children each having satisfactory clusion and each examined repeatedly uring a period of 6 years or longer.

The results are reported under the three aptions: (1) widths of the upper and wer dental arches, (2) depths of the up- er and lower dental arches, and (3) in- ces of the form of each dental arch. All hree sections present *group findings* in rms of central tendency and variability t selected ages, and *individual findings* ith respect to amount of annual change, ariety of growth curve, and association etween traits.

SOURCE OF DATA

Maxillary and mandibular hydrocal asts, made from alginate-base hydrocol- id impressions, were available on 13 girls nd 16 boys enrolled in a longitudinal re- earch project begun in 1946 at the State niversity of Iowa.

The 29 subjects were North American hite children: 86% were third-genera- on residents and the balance (4 sub- cts) had at least two grandparents born n North America. For 25 of the subjects 86%), the ethnic stock of at least three randparents was northwest European. ocio-economically, the group was above verage: over 50% of the fathers were men with professional or managerial occupations.

For each subject:

1. Dental casts were available at semiannual intervals from age 9 years to age 12 years and at annual intervals from age 12 years to age 15 years. For many of the subjects, there were casts available at ages 8 years and/or at ages 16 and 17 years. The impressions and casts were made within a few days of the child's birthday or midpoint between birthdays.
2. Information was accessible indicating acceptable dental occlusion throughout the ontogenic period covered. Orthodontic appraisal on the subjects, made at each examination, never included recommendation for treatment. Thus, the subjects were considered to have consistently good occlusion, ranging from "acceptable" to "excellent."

MEASUREMENTS

Throughout this study, arch width refers to an interbuccal diameter of the dental arch at the permanent first molars and arch depth refers to a sagittal diameter from this line to an anterior point.

Many different definitions and techniques have been used in studying dental arch widths and depths.

Arch width. Meredith and Cox ('54) summarize buccal, lingual and intermediate landmarks that have been employed in measuring the transverse distance between the permanent first molars. Arch width measurements have also been made between posterior (distal) points on the tooth anterior to the permanent first molar.

---

[1] Supported in part by research grant D-217 from the National Institute for Dental Research, of the National Institutes of Health, U. S. Public Health Service.

Use of the permanent first molars in measuring width of the posterior segment of the dental arch has the advantage of continued availability from age 9 years or younger. For the present study, then, these teeth were used.

Since it has been shown (Meredith and Cox, ’54) that measurement of maximum transverse diameter could be determined with high reliability, this method was adopted as the starting point for this study. However, the exact locations on the teeth of the points yielding maximum diameter at one age might vary slightly from the points yielding maximum diameter at another age. Strictly comparable anatomic landmarks from age to age were desirable not only for this measurement but also since it was planned to mark and use the same landmarks in deriving measures of arch depth.

It was decided to obtain the maximum diameter at age 12 years and carefully mark, with a hard pencil, the point on each molar that gave this maximum. Using this anatomic reference, all casts of the same arch for a given subject were marked, one side at a time. To aid in placing dots at the desired locations, calipers with fine sharpened ends, set for the distance from the 12-year point to the buccal groove, were used to locate the landmark at other ages. The point-groove distance, although constant for one series of arches on a given subject, varied between 2 and 3 mm for different series (upper and lower) and/or different subjects. A magnifying lens was also used to increase the precision. The procedure was repeated on each side of the two arches. The points on either side of the arch are designated A and B, and the straight-line distance between them defined as arch width.

From unpublished material, measurements of maximum interbuccal diameter at the permanent first molars were available on the upper and lower arches of 23 of the children in this study. Combining the data for the two arches, 46 algebraic differences between maximum diameter determined on unmarked casts and arch width as defined in this study were tabulated at three ages: 9 years, 12 years and 15 years. The mean values for the distributions did not differ significantly fr each other. The largest difference was age 15 years, the maximum diameter av aging 0.13 mm larger than the distan between the marked points. The standa deviations of the three difference distrib tions were 0.13 mm, 0.09 mm and 0. mm, respectively. The standard deviati at age 12 years was lower than at the oth two ages and essentially is an index reliability of measurement. At ages 9 yea and 15 years, differences in the two met ods would include, besides a check on liability, any changes in the position of t teeth. For these two ages, the maximu diameter determined on unmarked cas was never more than 0.5 mm larger th the diameter determined from points and B. Over 80 % of the differences we 0.2 mm or smaller, and less than 10 were as large as 0.4 mm or 0.5 mm.

Arch depth. The term “arch depth” used here as applying to a straight-li distance from an anterior landmark to posterior landmark. (This antero-pos rior dimension has frequently been call “arch length.”) Anterior landmarks th have been used include the following:

1. Point of intersection of the line co necting the most *lingual* aspects of t central incisors at their mesial margin ridges and the sagittal line between t central incisors (Brown and Daugaar Jensen, ’51).
2. Midpoint of a line tangent to t *labial* surfaces of the central incisors (B row and White, ’52; Moorrees, ’59).
3. The point located by the intersecti of the line drawn through the center of t first *incisal* edges and the median li (Sillman, ’51).
4. Center of the central incisors at t gum level (Goldstein and Stanton, ’35).
5. Intradentale superioris linguale (He riques, ’53).

Posterior landmarks previously used i clude the midpoints of lines connectin

1. The most dorsal points on the dist surfaces of the second deciduous molar second bicuspid (Moorrees, ’59).
2. The *mesial grooves* of the permane first molars at the ridge level (Sillman, ’5
3. The *centers* of the molars at the gu line (Goldstein and Stanton, ’35).

4. The *buccal grooves* where they pass
the occlusal surfaces (Brown and Dau-
ard-Jensen, '51).

5. The contact points between the per-
anent first and second molars on the
dsagittal plane (Henriques, '53).

The method of deriving midpoints of
ese lines frequently has not been speci-
d.

In the present study, the steps in deter-
nation of arch depth include marking
ree points, measuring three distances,
d deriving arch depth by formula.

The mark for the anterior landmark
) was placed at the most lingual point
the labial surface of the impression of
gingival tissue, midway between the
rmanent central incisors. The cast for
e arch at age 12 years was marked first
d, using a magnifying lens, points on
other casts of that arch for the same
bject were marked at one time, to reduce
possibility of slight change in placing
point at different ages. The procedure
s then repeated for the other arch.

The three distances, AB (arch width),
and BC were measured with sliding
rnier calipers and recorded to the near-
0.1 mm. Two independent sets of
asurements were made by the same in-
idual. The average of the two obser-
tions for a given distance was used ex-
pt when the two records differed by more
an 0.2 mm. In the latter instances (less
an 10% of the paired readings), addi-
nal sets of independent readings were
ken and all observations averaged after
carding obvious misreadings.

Arch depth (the distance from C to the
dpoint of AB) was computed from the
ree measurements by the formula for
median of any triangle with known
es.[2]

Widths of the upper and lower dental arches

Group findings. The means, standard
viations, maximum and minimum val-
s for the same 13 girls and 16 boys at
ccessive ages from 9 years to 15 years
presented in table 1. Curves drawn to
means for each arch-sex subgroup are
own in figure 1. The curves are ex-
nded in each direction to cover the age interval from age 8 to age 17 years. The additional points were obtained with the aid of width measurements for 12 girls and 16 boys at age 8 years; 12 girls and 12 boys at age 16 years; 6 girls and 8 boys at age 17 years. The procedure used in determining these points can be illustrated as follows. Mean upper arch width at age 15 years for the entire sample of 16 boys is 59.7 mm. Mean change for 12 of these boys between ages 15 and 16 years is 0.09 mm. Combining these two figures gives a value of 59.8 mm, representing mean upper arch width at age 16 years. This method avoids the distortion of a mean trend that can result from utilizing an average for only a portion of the subjects.

Selected findings from table 1 and figure 1 are:

1. Boys show continuing increase in mean arch width over the age period studied. The magnitude of the increase between ages 9 and 15 years is 2.4 mm in the upper arch and 2.1 mm in the lower arch. For girls, the changes over the same period are 1.4 mm and 1.6 mm, with the curves leveling off at age 13 years, rather than showing a continued rise as for the boys.

2. The mean curves for width of the two arches on children of a given sex are approximately parallel, the curve for the upper arch lying 3.3 to 3.7 mm above that for the lower arch throughout the period of ontogeny investigated.

3. In the maxillary arch, the mean value for boys exceeds that for girls by 3.6 mm at age 9 years and by 4.6 mm at age 15 years. Corresponding values in the mandibular arch are 3.8 mm and 4.3 mm. Tests of significance yield *t*'s larger than 4.0 at all ages for both arches,[3] allowing rejection of the hypothesis that these differences are due to chance variation in samples from the same population with respect to width of the dental arches. The minimum values for males lie near or above the mean values for the females, and the maximum values for the girls approximate the mean values for boys.

---

[2] $\sqrt{\frac{\overline{AC}^2 + \overline{BC}^2}{2} - \frac{\overline{AB}^2}{4}}$

[3] When $t = 4.0$, with 27 *df*, $P < 0.01$.

TABLE 1

Central tendency and variability values for dental arch width (in millimeters) at successive ages for 16 boys and 13 girls

Age	Mean		Standard deviation		Minimum		Maximum	
	Males	Females	Males	Females	Males	Females	Males	Females
years				Upper arch				
9.0	57.3	53.7	2.03	2.11	53.4	49.9	61.2	57.4
9.5	57.6	54.0	1.79	2.12	55.0	49.9	61.2	57.4
10.0	58.0	54.2	1.90	2.18	55.4	50.0	61.3	57.8
10.5	58.2	54.4	1.81	2.29	55.5	50.1	61.5	58.5
11.0	58.5	54.7	1.86	2.26	55.7	50.5	61.4	58.9
11.5	58.6	54.8	1.90	2.27	55.5	50.1	61.9	58.8
12.0	58.8	55.0	1.91	2.24	55.6	50.8	61.8	59.2
13.0	59.0	55.2	1.80	2.19	55.6	52.0	61.8	59.4
14.0	59.4	55.2	1.92	2.23	56.0	51.6	62.0	59.1
15.0	59.7	55.1	1.93	2.28	56.1	51.3	61.8	59.1
				Lower arch				
9.0	53.9	50.1	1.89	2.40	50.8	45.0	57.8	54.6
9.5	54.2	50.4	1.77	2.39	52.0	45.1	58.0	54.0
10.0	54.4	50.6	1.72	2.45	52.0	45.7	58.0	54.9
10.5	54.7	51.0	1.48	2.48	52.9	46.5	57.7	55.4
11.0	55.1	51.3	1.43	2.40	53.0	47.0	57.5	55.5
11.5	55.3	51.4	1.58	2.44	53.3	46.8	58.0	56.0
12.0	55.4	51.5	1.49	2.44	53.6	47.2	58.2	56.0
13.0	55.6	51.6	1.61	2.44	53.2	47.7	58.7	56.0
14.0	55.8	51.8	1.68	2.34	53.3	47.9	58.9	56.0
15.0	56.0	51.7	1.58	2.39	53.3	47.8	59.0	56.0

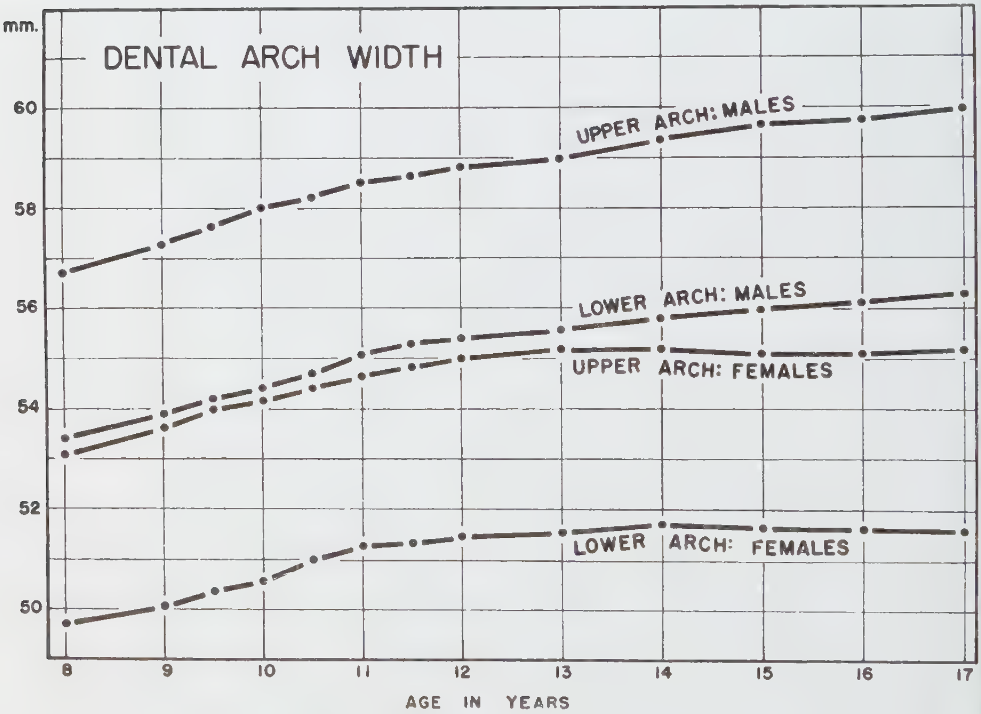


Fig. 1 Mean trends of maxillary and mandibular dental arch width at the permanent first molars, based on data presented in tables 1, 2, and 3.

4. The range of measurements of den- arch width for the girls in this sample larger than for the boys. The standard viations reflect this larger dispersion. sts of the difference of the two estimates population variance, yield F's too small reject the hypothesis that the samples me from the same population, except three age groups with respect to man- ular width. Differences as large as se obtained in lower arch variance of two sexes at ages 10.5 years, 11 years, d 12 years would occur in random sam- ng from the same population less than of the time. It should be noted that tests at each age are made on the same ups of children and, hence, are not lependent.

Barrow and White ('52) measured den- arch width at the first molar "where the ccal groove crosses the ridge into the ntral fossae." They used 528 set of casts 51 children and found mean *decreases* 0.4 mm in the upper arch and 0.9 mm the lower arch over the age period from to 15 years. In the present study, over s same age period, mean *increases* are nd for both arches of both sexes. In upper dental arch, the increases are mm and 0.4 mm for boys and girls pectively; corresponding values for the ver arch are 0.9 mm and 0.4 mm. The studies differ in method and popula- n sampled. The present one measures dth at the base of the first molar rather n at the occlusal surface and is made y on subjects with acceptable occlu- n.

Cohen ('40) measured dental casts on boys and 13 girls who had not received hodontic treatment. He found "the size the upper arch of the girls was slightly ger than that of the boys, but in the ver arch there is a more distinct differ- e" (p. 1257). Other studies have con- ently reported a sex difference in the ection of larger arches for the males. the present study, the means of the les exceed those of the females by simi- amounts (between 3 and 4 mm) in h arches.

Between ages 9.5 years and 13.5 years, hen found an increase of approximately mm in the upper arch, but essentially no change in the lower arch. He measured arch width between the mesiolingual cusps of the permanent first molars. In the present study, from age 9.5 years to 13 years, the *increase* is 1.4 mm in both arches for the boys and 1.2 mm in both arches of the girls.

Individual findings. The course of change in width of each arch is presented in table 2 for each of the 16 male subjects and in table 3 for each of the 13 female subjects. The obtained widths at ages 9 and 15 years are listed, along with annual and composite changes over this period. Also included are values, where these are available, for the change between 8 and 9 years and changes subsequent to 15 years.

From these tables, it may be noted that:

1. Of the 58 changes for the age span from 9 years to 15 years, there are only two which show a decrease. The upper arch of one girl decreases 0.1 mm and the lower arch of one boy shows a loss of 0.5 mm. The bulk of the changes (97%) are in the direction of increase, ranging from 0.1 mm to 4.7 mm.
2. Eleven of the 16 boys show a greater increase in upper arch width than in lower width. The reverse tendency is found for girls: 10 of the 13 have a larger increase in mandibular arch width than in maxillary arch width.
3. The period of largest annual change is modally 9 to 10 years in the upper arch and 10 to 11 years in the lower arch. For some individuals, however, the largest annual changes are found to occur after age 12 years.
4. An increase in average width is found between 8 years and 9 years, while mean annual changes after age 15 years are all small in amount, averaging only slightly above zero.

Moorrees ('59, pp. 214, 218) presents annual increments in arch width at the first permanent molar, though these increments are not on the same group of children at all ages. Measurements were made between the crown tips of the mesiolingual cusps. The mean annual increments obtained by Moorrees are smaller than those obtained here. The sum of mean changes over the 4-year period from

TABLE 2

Annual changes in dental arch width (in millimeters) for 16 boys with satisfactory occlusion

Subject	Width at age 9 years	Age interval (years)									
		8–9	9–10	10–11	11–12	12–13	13–14	14–15	9–15	15–16	16–17
					Upper arch						
1	58.3	1.0	1.3	0.5	0.4	0.5	0.3	0.5	3.5	0.2	0
2	58.9	0.9	0.5	0.9	0.2	0.1	1.0	0.1	2.8	−0.1	0.3
3	56.0	0.4	1.0	0.2	0.5	0.3	0.7	0.2	2.9	−0.1	0.2
6	61.2	0.6	0.1	0.1	0.3	−0.5	0.8	−0.5	0.3	−0.2	0.3
9	55.1	0.1	0.3	0.6	−0.4	0	0.4	0.1	1.0	0.5	0.4
10	58.0	1.0	0.2	0.7	0.2	−0.2	0	0.4	1.3	−0.2	0
19	53.4	−0.4	2.2	0.1	0.6	0.7	−0.1	0.1	3.6	—	—
24	59.0	0.9	0.1	1.0	−0.3	0.2	0.2	0.3	1.5	−0.2	—
28	60.4	—	0.6	0.3	0.5	0	0.6	0.6	2.6	0.4	0.3
33	56.4	1.3	0.9	0.8	0.5	−0.4	0.1	0.3	2.2	—	—
35	55.2	0.8	0	0.7	0.1	1.0	0	0.9	2.7	0.6	—
38	56.4	0.4	0.7	0.6	0.4	0.3	0.2	0.4	2.6	0.2	—
40	59.1	0.3	0.6	0.5	0.1	0.7	0.3	0.5	2.7	−0.2	0
41	55.6	1.2	0.4	0.4	0	0.2	0.8	0.1	1.9	0.2	—
47	57.0	0.4	1.2	0.6	0.2	1.0	−0.1	−0.5	2.4	—	—
51	56.5	0.5	1.1	0.9	0.3	0.5	0.6	0.7	4.1	—	—
Mean	57.3	0.63	0.70	0.56	0.23	0.28	0.36	0.26	2.38	0.09	0.19
					Lower arch						
1	57.1	1.6	−0.1	0.4	0.5	0.8	0.2	0.1	1.9	0	0
2	55.0	0.8	0.6	0.5	0.5	0.2	0.2	0.2	2.2	−0.2	0.4
3	54.6	0.7	0.4	0	0.7	−0.1	0.4	0.1	1.5	0	0.3
6	57.8	0.6	0.2	−0.5	0.4	0.1	0.1	−0.8	−0.5	—	—
9	52.6	0	−0.1	0.9	0.2	−0.4	0.1	0	0.7	0.3	0.4
10	54.1	0.3	0.1	0.8	0	−0.4	0	0.1	0.6	−0.4	—
19	50.8	−0.4	1.2	1.0	0.9	0.1	0.3	0.6	4.1	—	—
24	54.0	0.3	0.1	0.6	−0.4	0.4	0.2	0.3	1.2	0.3	—
28	56.2	0.3	0.6	0.7	0.7	0.1	0.3	0.2	2.6	0.3	0.2
33	52.4	0.6	0.6	1.3	0.8	−0.3	0.2	0.4	3.0	—	—
35	52.4	0.1	0.4	0.6	0.5	0.4	0	1.3	3.2	0.4	—
38	52.7	0.4	0.7	1.4	0	0.1	−0.1	0.1	2.2	0.1	—
40	54.3	0.1	0.8	1.0	−0.4	0.5	0.2	0.1	2.2	0.2	0
41	51.3	0.1	1.0	1.1	0	0.3	0.2	0.2	2.8	0	—
47	53.7	0.7	0.7	0.5	0.2	0.2	−0.1	0	1.5	—	—
51	53.0	1.0	1.0	1.0	0.5	0.5	1.1	0.6	4.7	—	—
Mean	53.9	0.45	0.50	0.71	0.32	0.16	0.21	0.22	2.12	0.06	0.21

TABLE 3

Annual changes in dental arch width (in millimeters) for 13 girls with satisfactory occlusion

Subject	Width at age 9 years	Age interval (years)									
		8–9	9–10	10–11	11–12	12–13	13–14	14–15	9–15	15–16	16–17
					Upper arch						
8	53.7	0.3	1.0	0.9	−0.4	−0.1	0.5	−0.2	1.7	0	−0.1
10	57.4	1.1	0.4	1.1	0.3	0.2	−0.3	0	1.7	0	0.2
18	54.5	0.5	0.4	0.4	0	−0.2	0.3	0.2	1.1	−0.1	—
20	56.4	0.4	1.3	0.3	0.3	0	0.1	0.2	2.2	−0.1	0.4
32	54.9	0.6	−0.4	0.2	0.4	0.2	−0.2	−0.3	−0.1	0.1	0
39	54.6	0.9	0.4	1.0	0.7	0.8	0.1	0	3.0	0.4	—
41	49.9	0.3	0.1	0.5	0.3	1.2	−0.4	−0.3	1.4	−0.2	0
47	52.3	0.7	0.2	0.5	0.9	−0.5	−0.3	−0.3	0.5	0.1	—
49	51.3	0.6	1.1	0.6	0	0	0.1	0.1	1.9	−0.1	—
46	55.8	0.6	0.4	0.5	0.3	0	0	0	1.2	0	—
19	51.2	0.5	0.5	0.5	0.5	0.1	0.1	−0.1	1.6	0.3	0.2
43	52.8	—	0.6	0.5	0.3	−0.1	0	−0.8	0.5	−0.3	—
59	53.3	1.0	0.5	0.1	0.1	0	0	0.2	0.9	—	—
Mean	53.7	0.63	0.50	0.55	0.28	0.12	0	−0.10	1.35	0.01	0.11
					Lower arch						
8	51.0	−0.2	1.2	1.2	−0.1	−0.1	0	0.1	2.3	0.1	−0.2
10	53.3	0.7	0.7	0.5	0.7	0.6	0.2	0	2.7	0.1	0.2
18	52.7	0.6	0.4	0.6	−0.1	0.2	0.2	0	1.3	0	—
20	54.6	0.9	0.3	0.6	0.5	0	−0.3	−0.1	1.0	0	0.1
32	50.0	0.1	−0.4	0.6	0.3	0.1	−0.1	−0.4	0.1	0.1	−0.2
39	49.4	0.7	0.3	0.7	0.6	1.0	0	0	2.6	0	—
41	45.0	−0.8	0.7	1.3	0.2	0.5	0.2	−0.1	2.8	−0.1	−0.1
47	48.5	0.5	0	0.5	0.2	0.3	0	0.1	1.1	0	—
49	50.0	1.3	0.3	0.5	−0.2	0.1	−0.1	−0.1	0.5	0.1	—
46	51.0	0	1.0	0.6	0.2	0	0	0.1	1.9	0.1	—
19	47.9	−0.2	0.5	0.3	0.7	0.2	0.6	−0.2	2.1	0	0
43	49.2	—	0.4	1.1	−0.2	−0.8	0.4	−0.2	0.7	−0.3	—
59	49.1	0	0.4	0.5	−0.1	0.1	0.6	0	1.5	—	—
Mean	50.1	0.30	0.45	0.69	0.21	0.17	0.13	−0.06	1.58	0.01	−0.03

age 9 years to age 13 years is, from his data on the upper and lower arches respectively, 1.5 mm and 0.4 mm for boys, 0.8 mm and 0.5 mm for girls. Comparable totals from the present study are 1.8 mm and 1.7 mm for boys, and 1.5 mm in both arches for girls.

Longitudinal records of arch width at the permanent first molar, as derived from frontal and lateral roentgenograms, are presented by Woods ('50, pp. 688–689). For 12 boys and 12 girls, there are data at both age 9 years and 15 years. Averaging the changes for each group over this age period, increases in the upper arch are 1.4 mm for boys and 1.1 mm for girls. In the lower arch, the mean changes are 0.7 mm for boys and −1.0 mm for girls. These changes are smaller than comparable values given in tables 2 and 3, particularly in the lower arch. It may also be noted that, in the present study, 28 (97%) of the 29 changes in lower dental arch width from 9 years to 15 years, are in the direction of increase: in Woods' group of 24 subjects measured at both these ages, only 8 (33%) registered an increase, with the balance showing no change, or decreases up to 2.5 mm.

Curves for width of the upper and lower arch were plotted for each of the 29 subjects. Study of the individual graphs revealed that although many curves were roughly similar to the pattern for the group, some curves showed little change and a few showed decrease. The curves do not fall into clearly discrete types, but a picture of variations may be given by dividing them into 4 groups.

Group A. Curves similar to the mean trends: that is, an initial increase of 1 to 3 mm, followed by a leveling off (no annual increase after age 14 years as large as 0.5 mm).

Group B. Curves showing continued increase in width up to at least age 15 years, with the change between 14 and 15 years of 0.5 mm or more.

Group C. Curves showing an increase of at least 1 mm in width (1.4 to 2.1 mm) followed by a decrease of about 1 mm (0.7 mm to 1.2 mm).

Group D. Curves showing 1 mm or less total change over the full 6 years but not falling in group C.

The frequencies for each curve, tabulated with respect to sex and dental arch are shown in table 4.

Sixty-four per cent of the curves are in group A. The age at which the curves show a change in slope varies between 11 years and 14 years. Illustrations of this most frequently observed pattern are shown in the left panel of figure 2 for three subjects.

Among the individual curves for boys there are 8 which show continued increase of at least 0.5 mm between ages 14 years and 15 years: 5 of the upper arch and three of the lower arch. Two of the group B curves are shown for subject M51 in figure 2. None of the trends for girls fell into this grouping.

Four of the 26 curves for girls were in group C. Specifically, the upper arch width curves for F41 and F47, and the upper and lower arch width curves for F43 followed this pattern (see fig. 2). The lower arch of one boy is represented in this group showing a decrease over the later years.

The group (D) showing little change over the entire 6-year period contains curves (14%). Only one individual (F32)

TABLE 4

The number of individual dental arch width curves in each of 4 groups

Group	Males Upper arch	Males Lower arch	Males Both arches	Females Upper arch	Females Lower arch	Females Both arches
A	10	10	20	8	9	17
B	5	3	8	0	0	0
C	0	1	1	3	1	4
D	1	2	3	2	3	5
Total	16	16	32	13	13	26

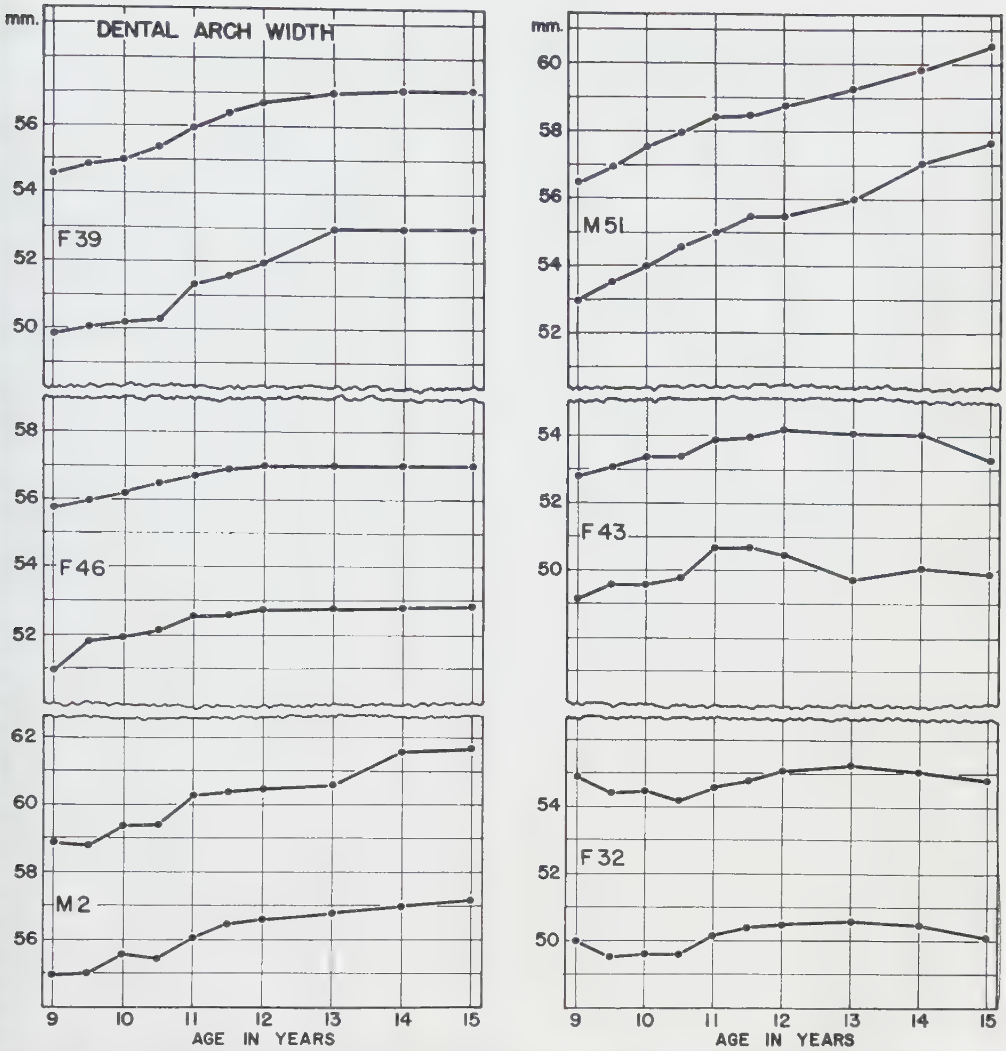


Fig. 2 Individual trends for maxillary and mandibular dental arch width. The curves in the left panel are from group A, representative of over 60% of the curves. On the right, from top to bottom are cases from groups B, C, and D, respectively.

ad this pattern in the width of both up-er and lower dental arches.

Coefficients of correlation were com-uted: (1) between dental arch widths t 4 selected ages for each arch; (2) be-ween width of a given arch at age 9 years nd the change in width of that arch from years to 15 years; (3) between change n width from age 9 years to age 11 years nd change during the following 4 years; 4) between upper and lower dental arch vidth at 4 ages; and (5) between changes from 9 years to 15 years in the upper arch and the lower arch.

Because of the difference in range of values for the two sexes, the correlation coefficients were computed separately for the 16 boys and 13 girls. The obtained coefficients for the same pair of variables were combined through use of Fisher's transformation of *r* (Rosander, '51, p. 611) to give a more reliable estimate of the relationship. The resulting values are given in table 5.

The correlation coefficients for width of a specified dental arch at different ages are high, ranging from 0.86 to 0.98. The magnitude of these coefficients is explained by the very small changes with age relative to the variability of arch width at the initial ages.

The correlation between increments from 9 to 11 years and the increments from 11 years to 15 years does not differ significantly from zero in either arch. Results from correlating arch width at age 9 years with the change over the subsequent 6 years show no significant association between the variables in the upper arch. In the lower arch, the r of -0.41 is significant at the 5% level of confidence.

Visual examination of the 29 sets of curves for the two dental arches revealed a fairly close paralleling of the two curves for most subjects. The correlations at 4 ages also indicate that a moderately high relationship (r's = 0.85 to 0.90) i maintained between the upper and lowe arch for this group of subjects. The cor relation between change in the upper arc width and change in lower arch widt over the 6-year period is 0.73.

Meredith and Cox ('54) obtained r's o 0.76 for 44 boys and 0.79 for 50 girl between upper and lower arch width a age 9 years. Comparable figures from thi study are 0.85 and 0.86. Smyth and Youn ('32) found partial correlation coefficients with age constant, of 0.83 for boys an 0.78 for girls between maxillary and man dibular width at the first permanent molar

Individual differences between th widths of the two arches (maxillary arc width minus mandibular arch width) wer distributed at 4 ages. The means an ranges for these distributions are show in table 6. For both sexes, the mean dif ferences fall between 3.4 mm and 3.7 m

TABLE 5

Correlation coefficients of arch width and arch width changes

Width at: Years	9	11	13	15	Change: 9–15	11–15
			Correlation between ages			
			Upper arch			
9		0.97	0.92	0.91	–0.15	
11			0.97	0.96		
13				0.98		
Change: 9–11						0.21
			Lower arch			
9		0.96	0.92	0.86	–0.41	
11			0.96	0.91		
13				0.97		
Change: 9–11						0.13
			Correlation between arches			
	0.85	0.90	0.88	0.89	0.73	

TABLE 6

Means and ranges (in millimeters) of upper arch width minus lower arch width

Age	Mean		Minimum		Maximum	
	Males	Females	Males	Females	Males	Females
years						
9.0	3.4	3.6	1.2	1.3	5.0	5.2
11.0	3.4	3.4	2.2	1.6	5.8	5.6
13.0	3.4	3.6	2.3	1.3	5.3	5.5
15.0	3.7	3.4	2.1	1.6	5.3	5.6

TABLE 7

Central tendency and variability values for dental arch depth (in millimeters) at successive ages for 16 boys and 13 girls

Age	Mean		Standard deviation		Minimum		Maximum	
	Males	Females	Males	Females	Males	Females	Males	Females
years								
				Upper arch				
9.0	36.7	34.9	0.99	1.53	35.0	32.5	38.2	37.2
9.5	36.8	35.2	1.09	1.50	34.7	32.2	38.2	37.1
10.0	36.7	35.3	1.12	1.44	34.3	32.8	38.2	37.1
10.5	36.9	35.2	1.15	1.52	34.6	32.6	38.6	37.6
11.0	37.1	35.1	1.23	1.51	34.8	32.8	38.7	37.2
11.5	37.0	35.0	1.28	1.62	34.2	32.7	38.6	37.6
12.0	36.7	34.9	1.32	1.69	33.7	32.8	38.2	37.8
13.0	36.0	34.3	1.26	1.65	33.3	32.0	37.3	37.4
14.0	35.6	33.7	1.36	1.53	32.9	31.5	37.2	36.8
15.0	35.2	33.4	1.38	1.35	32.8	31.6	37.0	36.0
				Lower arch				
9.0	32.6	31.7	1.64	1.24	29.2	29.6	34.8	35.1
9.5	32.5	31.6	1.55	1.24	29.3	29.5	34.6	34.9
10.0	32.5	31.4	1.60	1.26	28.8	29.2	34.7	34.7
10.5	32.4	31.2	1.43	1.33	29.5	28.9	34.3	34.4
11.0	32.3	30.9	1.48	1.53	29.3	28.6	34.6	34.5
11.5	32.0	30.4	1.63	1.59	28.6	28.1	34.5	34.4
12.0	31.6	30.0	1.82	1.80	27.7	27.4	34.3	35.0
13.0	30.7	29.3	1.72	1.53	26.5	27.3	33.7	33.9
14.0	30.2	28.7	1.55	1.43	26.6	26.9	32.7	33.1
15.0	29.9	28.5	1.62	1.34	25.7	26.8	32.3	32.6

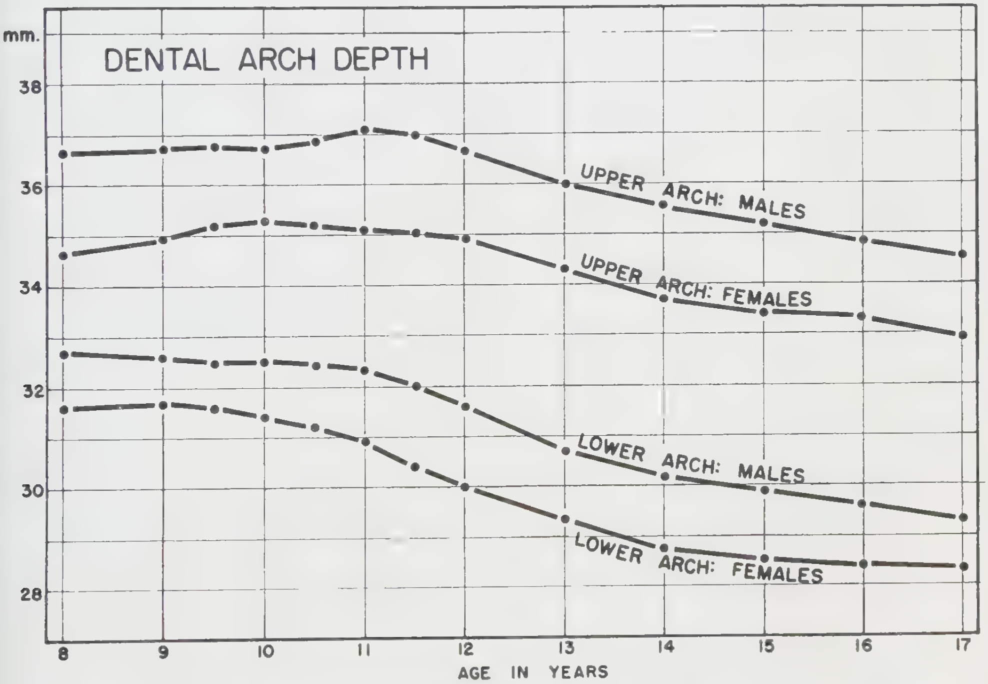


Fig. 3 Mean trends of maxillary and mandibular dental arch depth, based on data given in tables 6, 7, and 8.

TABLE 8

Annual changes in dental arch depth (in millimeters) for 16 boys with satisfactory occlusion

Subject	Depth at age 9 years	Age interval (years)									
		8–9	9–10	10–11	11–12	12–13	13–14	14–15	9–15	15–16	16–17
					Upper arch						
1	37.5	0.4	0.3	0.5	−0.1	−1.0	−0.1	−0.5	−0.9	−0.7	−0.2
2	36.6	−0.3	0.6	0.1	−0.9	−0.4	−0.4	−0.5	−1.5	−0.8	−0.2
3	36.5	−0.3	0	0	0.5	−1.2	−0.3	0	−1.0	−0.2	−0.6
6	37.3	−0.1	−0.1	−0.1	−0.3	−0.6	−0.6	−0.4	−2.1	0.2	−0.9
9	35.5	−0.7	−0.1	−0.1	0	−0.3	−0.9	−0.1	−1.5	−0.2	−0.3
10	35.2	0.1	−0.5	0.8	−0.7	−1.2	−0.6	−0.2	−2.4	−0.6	−1.1
19	38.2	1.2	−0.4	0.9	−0.3	−1.4	−0.4	−0.2	−1.8	—	—
24	35.0	−0.3	−0.7	0.5	−1.1	−0.4	−0.4	0.1	−2.0	−1.1	—
28	37.5	−0.1	−0.1	0.5	−0.4	−0.2	−0.1	−0.3	−0.6	−0.3	−0.3
33	36.3	−0.2	0.2	0.2	0.6	−1.1	−0.9	−1.0	−2.0	—	—
35	36.9	1.2	0.5	0.4	0.2	−0.7	−0.3	0	0.1	0.3	—
38	35.9	0	−0.2	−0.1	−0.7	−0.7	−0.3	−0.9	−2.9	−0.2	—
40	37.1	0.2	0.3	0.9	−1.5	−1.0	−0.1	−0.1	−1.5	−0.4	−0.1
41	38.0	−0.3	0.2	0.2	−0.7	−0.7	−0.1	−0.4	−1.5	−0.5	—
47	38.2	0.9	−0.6	0.9	−0.9	−0.6	−0.6	−0.2	−2.0	—	—
51	36.2	−0.6	0.6	−0.1	−0.2	0	−0.3	−0.5	−0.5	—	—
Mean	36.7	0.06	0	0.34	−0.41	−0.72	−0.40	−0.33	−1.50	−0.38	−0.31
					Lower arch						
1	33.9	−0.1	0.2	−0.1	−0.6	−1.5	−0.6	−0.2	−2.8	−0.2	−0.3
2	33.0	−0.4	0.4	−0.6	−1.1	−0.8	−0.7	−0.5	−3.3	−0.5	−0.6
3	33.0	−0.4	0.3	−0.2	−0.2	−2.0	−0.1	−0.7	−2.9	−0.3	−0.1
6	34.3	−0.1	−0.2	0.3	−0.8	−1.7	−0.9	−0.2	−3.5	—	—
9	31.1	−0.2	0	0.1	−1.0	−0.8	−0.4	−0.5	−2.6	−1.1	−0.3
10	29.2	0	−0.4	0.5	−1.6	−1.2	0.1	−0.9	−3.5	0.4	—
19	33.1	−0.1	−0.6	−0.1	−0.2	−0.4	−0.8	−0.3	−2.4	—	—
24	31.5	−0.1	−0.7	−0.6	−1.3	−0.4	−0.3	−0.2	−3.5	−0.3	—
28	33.8	0	−0.4	−0.6	−0.7	−0.5	−0.2	−0.7	−3.1	−0.1	−0.1
33	31.3	0.2	0.3	0.6	0.6	−1.8	−1.2	−0.5	−2.0	—	—
35	34.6	−0.1	0.1	−0.1	−0.3	−0.6	−1.0	−0.4	−2.3	−0.5	—
38	29.9	−0.1	0.3	−0.1	−1.5	−0.5	−0.3	−0.1	−2.2	−0.3	—
40	34.8	0.4	−1.2	−0.1	−1.4	−0.7	−0.3	−0.6	−4.3	−0.2	−0.3
41	34.1	−0.6	−0.2	−1.0	−0.7	−0.4	−0.3	−0.3	−2.9	−0.6	—
47	32.2	−0.5	−0.4	0.2	−0.1	−0.4	−0.3	0	−1.0	—	—
51	31.5	−0.1	0.4	−0.1	−0.9	−0.3	−0.3	0.3	−0.9	—	—
Mean	32.6	−0.14	−0.13	−0.16	−0.73	−0.88	−0.48	−0.36	−2.70	−0.34	−0.28

TABLE 9

Annual changes in dental arch depth (in millimeters) for 13 girls with satisfactory occlusion

Subject	Depth at age 9 years	Age interval (years)									
		8–9	9–10	10–11	11–12	12–13	13–14	14–15	9–15	15–16	16–17
					Upper arch						
8	36.5	0.5	0.1	−0.1	−0.8	−1.8	0.4	−0.3	−2.5	0.1	−0.3
10	35.8	0.2	0.5	−0.5	−0.5	−0.3	−1.4	−0.3	−2.5	0.1	−0.9
18	33.0	—	0.3	−0.2	−0.6	−0.5	−0.5	0.1	−1.4	−0.2	—
20	35.5	0.4	1.0	0.1	1.2	−0.6	−0.6	−0.6	0.5	−0.2	−0.5
32	34.7	0.2	0.4	−0.7	−0.7	−0.6	−0.1	−0.2	−1.9	−0.1	−0.3
39	32.1	—	0.7	0	0	−0.6	0.1	0.1	0.3	0.2	—
41	34.3	−0.4	0	−0.4	0	−0.5	−0.1	−0.6	−1.6	−0.2	0.2
47	34.9	—	1.1	−0.1	0	−1.2	−0.3	0.2	−0.3	—	—
49	37.2	—	−0.2	0.1	0.3	0	−0.6	−1.0	−1.4	—	—
46	35.9	−0.2	−0.1	−0.1	−0.4	−0.6	−1.2	−0.4	−2.8	−0.4	—
19	32.5	0.3	0.7	0.1	0.3	0.1	−1.6	−0.4	−0.8	—	—
43	36.5	—	0.6	0.1	−0.3	−0.8	−1.6	−0.8	−2.8	−0.1	—
59	34.5	0.7	0.2	−0.7	−0.5	−0.6	−0.1	−0.4	−2.1	—	—
Mean	34.9	0.21	0.41	−0.18	−0.15	−0.62	−0.58	−0.35	−1.48	−0.09	−0.36
					Lower arch						
8	31.5	0.7	0.3	0.5	−2.7	−0.2	0	−0.1	−2.2	−0.1	−0.2
10	32.1	0	0.3	−0.7	−1.3	−1.0	−0.6	−0.2	−3.5	−0.1	−0.2
18	29.6	—	−0.4	−0.6	−1.2	−0.1	−0.4	−0.1	−2.8	0.1	—
20	31.1	0.1	−0.1	0.4	0.3	−2.0	−1.0	−0.1	−2.5	−0.3	0
32	31.4	−0.3	−0.5	−1.6	−0.4	−0.5	0.5	−0.4	−2.9	0	−0.1
39	32.7	0.1	−0.1	−0.7	−0.9	−0.5	−1.5	−0.3	−4.0	0	—
41	31.4	−0.4	−0.7	−1.4	−0.7	−0.5	−0.6	0	−3.9	−0.1	0
47	32.3	0.5	−1.7	0.3	−1.4	−0.9	−0.1	−0.2	−4.0	—	—
49	35.1	0.4	−0.4	−0.2	0.5	−1.1	−0.8	−0.5	−2.5	—	—
46	31.9	0.1	−0.8	−0.6	−0.6	−1.0	−1.1	−0.4	−4.5	−0.2	—
19	30.4	0.1	0.2	−0.1	−0.8	−0.2	−1.6	−0.2	−2.7	—	—
43	31.8	—	−0.5	0.4	−2.0	−0.6	0	−0.3	−3.0	0.1	—
59	31.3	0	0.3	−2.2	−1.0	0	−0.3	0.1	−3.1	—	—
Mean	31.7	0.12	−0.32	−0.50	−0.94	−0.66	−0.58	−0.21	−3.20	−0.07	−0.10

(see also table 1). The spread of the differences is between 1.1 mm and 2.4 mm on either side of these mean values. At age 15 years, for example, maxillary arch width exceeds mandibular arch width by 1.6 mm for one girl and by 5.6 mm for another.

Depths of the upper and lower dental arches

Group findings. The group statistics for maxillary and mandibular dental arch depth are shown in table 7. Figure 3 portrays curves for each arch-sex subgroup drawn to the means from table 7. Following the method used with arch width, extensions of the lines one year prior to age 9 years and two years after age 15 years were made using changes over these intervals on portions of the total sample (see tables 8 and 9, columns 3, 11, and 12).

With respect to the period between ages 9 years and 15 years, table 7 and figure 3 show:

1. For boys, the means for maxillary arch depth increase slightly (0.4 mm) between ages 9 and 11 years, then decrease 1.9 mm between ages 11 and 15 years. In the male mandibular arch, there is slight decrease (0.3 mm) from 9 to 11 years and more marked decrease (2.4 mm) from 11 to 15 years.

2. For girls, the maxillary arch depth means rise 0.4 mm between 9 and 10 years, then fall 1.9 mm between 10 and 15 years. In the mandibular arch, the means decline 3.2 mm from 9 to 15 years and yield a trend that is first concave and later convex to the chronologic base line.

3. For this sample of subjects, the sex difference in mean upper arch depth varies between 1.4 mm (age 10 years) and 2.0 mm (age 11 years). In the lower arch, male means exceed corresponding female means by 0.9 mm (age 9 years) to 1.6 mm (age 11.5 years). Tests of significance of these differences allow rejection of the hypothesis of random sampling from the same population at the 1% level of confidence with respect to the upper arch depth at all ages. In the lower arch, tests of significance allow rejection of the null hypothesis from age 10 years through age 15 years at a level of confidence between 1 and 5%.

4. The difference in depth of the tw dental arches increases with age. Fo boys, the upper arch mean is larger tha the lower by 4.1 mm at age 9 years an by 5.4 mm at age 15 years. For girls, th mean difference increases from 3.2 m to 4.9 mm.

Individual findings. Tables 8 and list for each subject, maxillary and mandibular arch depth at age 9 years, an changes in each arch annually betwee this age and age 15 years. Where available, changes prior and subsequent t these ages are included. From thes tables, it will be seen:

1. Fifty-five of the 58 changes (95% in dental arch depth over the 6-year perio are decreases, ranging in amount fro 0.3 mm to 4.5 mm. One boy and tw girls register small (0.1 mm, 0.3 mm an 0.5 mm) increases in depth in the uppe arch.

2. Twenty-five of the 29 subject (86%) show a larger decrease in th lower than in the upper arch depth. Th range in difference of change of the tw arches in depth is from −0.7 m to 3.7 mm.

3. Reflecting variation in the time o replacement of posterior deciduous teet by their permanent successors, the tim of greatest annual arch depth chang (over 1.0 mm) varies from age 9 year to after 14 years.

4. The interval in which largest individual decreases occur is earlier in th mandibular arch than in the maxillar arch for 11 of the 13 girls (85%), bu this does not typify the pattern for th boys. Only 4 out of the 16 males (25% show a definitely earlier decrease in lowe arch depth.

5. Decrease in arch depth continue after age 15 years, especially for the boy with records after this age.

Brown and Daugaard-Jensen ('51) o a group of 24 subjects who had receive no orthodontic treatment measured arc depth on casts made at an age in the earl twenties. This depth was compared t depth on the earliest cast of the same subjects showing erupted permanent teet from the first molar forward. They foun an average decrease of 1.6 mm in dept of both the upper and lower arch. In th resent study, the decreases in arch depth etween the age at which all permanent eeth are erupted anterior to the first per-anent molar and age 15 years are 1.4 m for girls and 1.6 mm for boys in the pper arch. Comparable decreases in lower rch are 2.0 mm and 1.9 mm, respectively. hus, most of the decrease to be expected arch depth seems to have occurred by ge 15 years.

Annual changes in depth of the two ental arches are given by Moorrees ('59, p. 201–202). It should be noted that these hanges are on individual subjects but e same individuals are not included for very age interval. He reports the range, andard deviation, and mean for 5 of e intervals covered in this study. Total-g the mean decreases from age 9 years age 14 years, as presented by him, yields ery small decreases in the upper and wer arches: 0.3 mm and 0.2 mm for oys and 0.8 mm and 0.7 mm for girls. hese decreases are smaller than those r the period from 9 years to 14 years the present study: 1.2 mm and 2.3 mm the upper and lower arches on boys, nd 1.1 mm and 2.0 mm on girls.

Moorrees ('59, p. 91) states that "some hildren show an increase and others a ecrease in arch length, irrespective of the rection or amount of the mean change each age level. It is, therefore, hazard-us to utilize the average annual changes a guide to predict individual growth atterns in arch length." The present udy (strictly longitudinal and differing omewhat in method) does not substan-ate this generalization at the older ages.

n referring to tables 7 and 8, it will be oted that from about age 12 years, there a predominance of decrease for each dividual as well as for the mean. For xample, checking the individual changes r lower arch depth from 12 to 13 years, ows that all of the 29 subjects register decrease. Considering the *total* change the two arches of each individual for e three-year period from 12 years rough 15 years, in line with the direc-on of mean change, all subjects here ow a decrease in depth. The amount decrease varies from near zero to over mm, averaging approximately 1.5 mm for each arch of each sex. Thus, when depth is determined by methods and for children comparable to those used in this study, one would rarely expect an *increase* in depth over this three-year period around the time of eruption of the permanent bicuspids.

Speck ('50) measured lower dental arch length on enlarged photographs of casts along a line determined by the contact areas of the teeth. The mean change in this length dimension, from mixed to permanent dentition, was in the direction of decrease, though a small number registered an increase. He adds, (p. 224) "A large majority of cases indicated a decrease in the anteroposterior dimension of the arch during the transition from deciduous to mixed and from mixed to permanent dentition when this was measured along the midline from the central incisors to a transverse line connecting the mesial contacts of the first permanent molars." The data on this measurement of depth are not included in the study.

Individual graphs were made for upper and lower dental arch depth. All curves depicted some decrease over the later years. To clarify variations on this pattern, the curves may be classified into three groups:

Group R. Curves showing less than 1.0 mm *total* change over the interval from 9 years to 15 years (0.5 mm to − 0.9 mm).

The balance of the curves, all showing a total decrease of 1.0 mm or more, may be divided into:

Group S. Curves with a downward trend beginning at age 9 years.

Group T. Curves changing to a negative slope subsequent to age 9 years.

For each sex and arch, the number of curves in each group is shown in table 10.

Less than 16% of the curves fall into group R. In upper arch depth, three boys and 4 girls show little total change (less than 1.0 mm) from age 9 years to age 15 years. One boy (M51) falls in this group with respect to both the upper and lower arch.

Nearly one-third of the curves show no increase in depth subsequent to age 9 years, but rather a decrease from this age.

TABLE 10

The number of individual dental arch depth curves in each of three groups

Group	Males			Females		
	Upper arch	Lower arch	Both arches	Upper arch	Lower arch	Both arches
R	4	1	5	4	0	4
S	3	6	9	1	8	9
T	9	9	18	8	5	13
Total	16	16	32	13	13	26

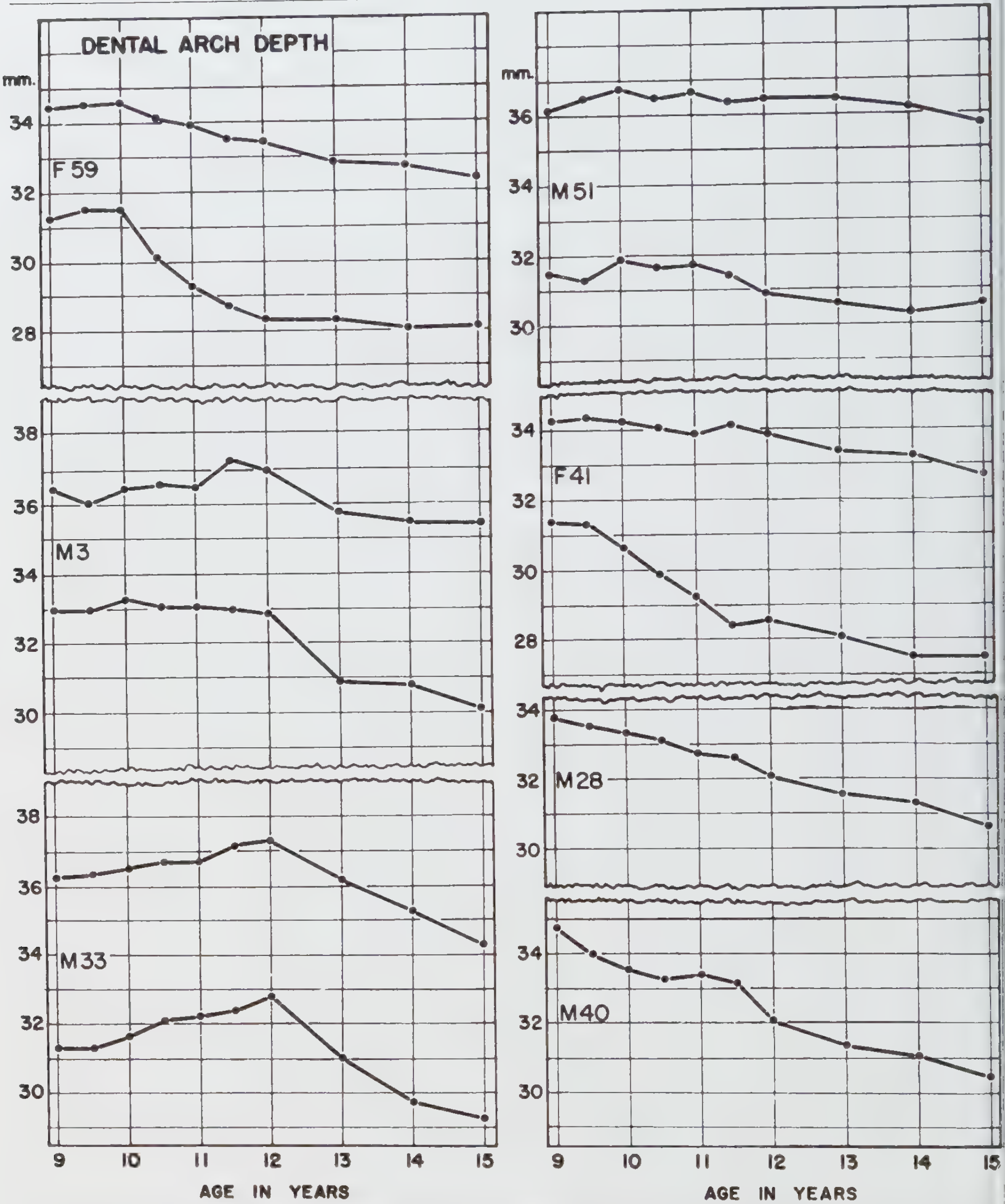


Fig. 4 Individual trends for maxillary and mandibular dental arch depth. The curves in the left panel are from group T, representative of over 50% of the curves. On the right, from top to bottom are curves from group R (M51) and group S (F41, M28, M40).

is group is comprised largely of curves r the mandibular arch.

The balance of the curves (53%) fall group T: the decrease in depth beginng sometime after 9 years of age and rying in amount between 1.0 mm and 0 mm.

Illustrations of these individual variaons of change in depth of the dental ches are presented in figure 4.

Coefficients of correlation were comuted: between dental arch depths at 4 lected ages for each arch; between depth a given arch at age 9 years and the ange in depth of that arch from 9 years 15 years; between upper and lower ntal arch depth at 4 ages; and between anges from 9 years to 15 years in the pper arch and the lower arch. The coicients were calculated separately for ales and females and then combined osander, '51, p. 611). The results are esented in table 11.

The depth of a given dental arch correted at different ages between 9 and 15 ars yields coefficients ranging from 0.80 0.95.

The correlation between depth at age years and change in depth over the next years does not differ significantly from ro for either arch.

For arch *width*, there was a significant sitive correlation between change in the o arches from 9 years to 15 years. For ch *depth*, the coefficient of 0.21 for ange of the two arches is too small to allow rejection of the hypothesis of zero correlation.

Examining the association between depth of the maxillary dental arch and depth of the mandibular arch, gives coefficients that increase from 0.63 at age 9 years to 0.86 at age 15 years. The difference between these terminal coefficients is significant at the 5% level of confidence. Smyth and Young ('32) found partial *r*'s of 0.73 for boys and 0.72 for girls with age constant.

While the difference between means for upper and lower dental arch *width* is found to remain constant (about 3.5 mm), there is an increase in the difference between upper and lower depth. Mean differences (maxillary arch depth minus mandibular arch depth) and the ranges for differences in the depth of the two arches are given at 4 ages in table 12. The upper dental arch depth is seen to be relatively larger at age 15 years than at age 9 years by somewhat over 1.0 mm.

Indices of the form of each dental arch

It is apparent from the material presented that the form of each dental arch changes between ages 9 years and 15 years, increasing in width and decreasing in depth. From the pair of values on each arch at each age, the ratio of arch depth to arch width (times 100) was computed.

TABLE 11

Correlation coefficients of arch depth and arch depth change

Depth at: *Years*	9	11	13	15	Change: 9–15
		Correlation between ages			
		Upper arch			
9		0.95	0.82	0.80	−0.12
11			0.88	0.87	
13				0.92	
		Lower arch			
9		0.88	0.87	0.86	−0.22
11			0.92	0.88	
13				0.95	
		Correlation between arches			
	0.63	0.69	0.82	0.86	0.21

Group findings. The mean, standard deviation and range at 10 ages are given in table 13 for the 4 arch-sex subgroups. Figure 5, presenting curves drawn to the 4 series of means shows:

1. At all ages, the maxillary dental arch is deeper relative to its width than the mandibular arch.

2. The mean trends for the girls are slightly and consistently above corresponding curves for the boys. Chance variation in sample means drawn from the same population would yield differences as large as those obtained at ages 9 years through 10.5 years in the mandibular arch, less than 5 times in 100. However, at all later ages in the lower arch and for all 10 age periods in the upper arch, th differences between mean depth/lengt indices of the two sexes are such that th two sex groups could well have come fro the same population.

3. During the 6-year period covere arch depth in percentage of arch widt decreases roughly by 5 points in the ma illary arch and 7 to 8 points in the mandibular arch.

Goldstein and Stanton ('35) in a cros sectional study found a tendency for arc depth to decrease in relation to arch widt from ages two years to 9 years. The state (p. 371), "This phenomenon is e pecially notable in the mandibular arc where the relative broadening is contin

TABLE 12

Means and ranges (in millimeters) of upper arch depth minus lower arch depth

Age	Mean		Minimum		Maximum	
	Males	Females	Males	Females	Males	Females
years						
9.0	4.1	3.2	3.0	−0.6	6.0	5.0
11.0	4.8	4.2	2.7	0.9	6.5	5.2
13.0	5.3	5.0	3.6	1.7	7.1	7.5
15.0	5.3	4.9	4.4	3.2	7.1	7.4

TABLE 13

Central tendency and variability value for dental arch form (100 × depth/width) at successive ages for 16 boys and 13 girls

Age	Mean		Standard deviation		Minimum		Maximum	
	Males	Females	Males	Females	Males	Females	Males	Females
years								
				Upper arch				
9.0	64.3	65.0	3.00	3.65	59.3	58.8	71.5	72.5
9.5	63.9	65.2	2.83	3.54	58.8	58.5	69.3	71.8
10.0	63.4	65.2	2.78	3.25	58.0	59.6	68.2	70.6
10.5	63.5	64.8	2.82	3.43	58.5	58.8	68.8	70.4
11.0	63.4	64.2	2.94	3.36	57.9	58.6	69.5	70.0
11.5	63.2	64.0	2.90	3.60	57.4	58.0	68.0	69.7
12.0	62.6	63.6	3.22	3.64	56.4	57.8	68.2	70.6
13.0	61.0	62.3	2.79	3.75	55.5	56.0	65.4	70.6
14.0	59.9	61.3	2.81	3.62	54.7	56.0	64.9	69.3
15.0	59.1	60.7	2.85	3.34	54.5	56.3	63.9	67.2
				Lower arch				
9.0	60.5	63.5	3.26	4.05	54.0	56.2	66.5	70.2
9.5	60.0	62.8	2.91	3.92	54.2	55.6	66.0	69.6
10.0	59.7	62.3	2.91	3.77	53.1	55.0	65.7	69.0
10.5	59.2	61.4	2.75	3.68	54.5	53.6	63.8	67.9
11.0	58.7	60.4	2.69	3.59	53.3	53.3	64.8	67.9
11.5	57.9	59.2	2.91	3.61	52.0	52.3	64.4	67.7
12.0	57.0	58.3	3.18	4.08	50.4	51.1	63.6	69.2
13.0	55.3	56.9	3.16	3.88	48.5	50.7	62.1	66.9
14.0	54.2	55.6	2.77	3.81	48.7	49.8	60.2	65.4
15.0	53.4	55.3	2.74	3.74	46.9	49.6	58.1	64.6

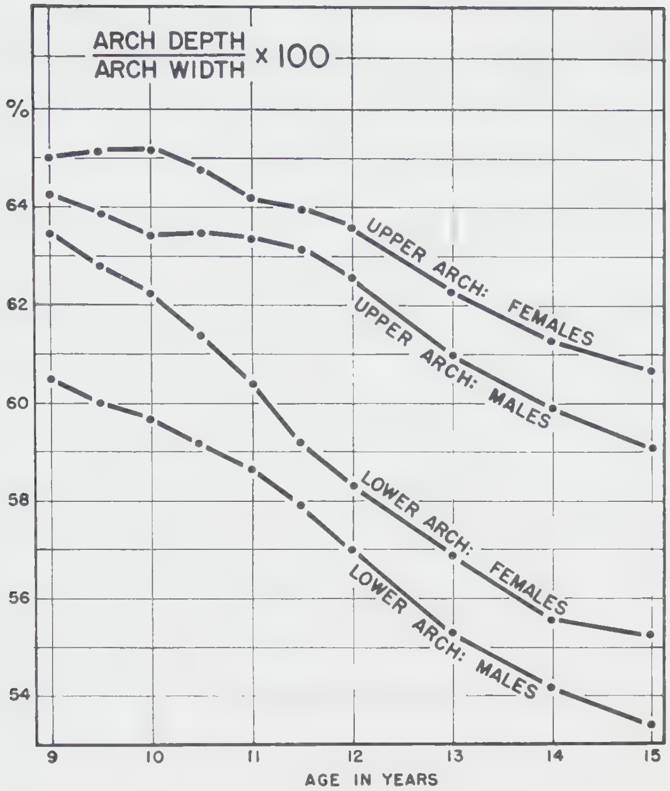


Fig. 5 Mean trends of maxillary and mandibular dental arch index, based on data in table 13.

us and proceeds at a greater rate than is pparent in the maxillary arch." In the resent study, this relative broadening ontinues from age 9 years through adoscence.

Individual findings. The range of inividual change in form of the arches ver the 6-year period studied extends rom a decrease of one point (upper arch f F47) to a decrease of 12 points (lower rch of F41).

Twenty-seven of the 29 cases (93%) ad a greater decrease in the lower index han in the upper.

Examples of variation in form and of hange in form, as found in this group f children, are presented in figure 6. hese include the subject with the relaively deepest arch (F49) and the relaively widest arch (M10).

Three subjects (F39, F41 and M40) howed an initial reversal of the relation of the indices for the two arches; the graph of one of these is included.

The individual curves for subject F10 are similar in form to the pattern exhibited by the trend of the means (fig. 5).

Table 14 presents coefficients of correlation for the indices, covering series of associations similar to those included under arch width and arch depth.

Intercorrelations obtained for indices of a given arch between 4 ages are all above 0.87. The correlation coefficients obtained for depth in percentage of width in the upper and in the lower arch increased from 0.66 at age 9 years to 0.84 at age 15 years.

The form of the lower arch at age 9 years and change in the form of this arch over the following 6 years, yields a correlation significantly different from zero ($r = -0.48$). In other words, there is some tendency for mandibular arches which have high indices at age 9 years to show greater decrease than the average between 9 years and 15 years.

There is no relationship ($r = 0.01$) between change in the index for the upper arch during the 6-year period and the change over the same period in the lower arch index. In addition to correlatior shown in table 14, r's were computed b tween width and depth for each arc separately at 4 ages. These coefficien ranged from 0.00 to 0.27, indicating b another approach, that dental arches f children with good occlusion, show co siderable variation in form.

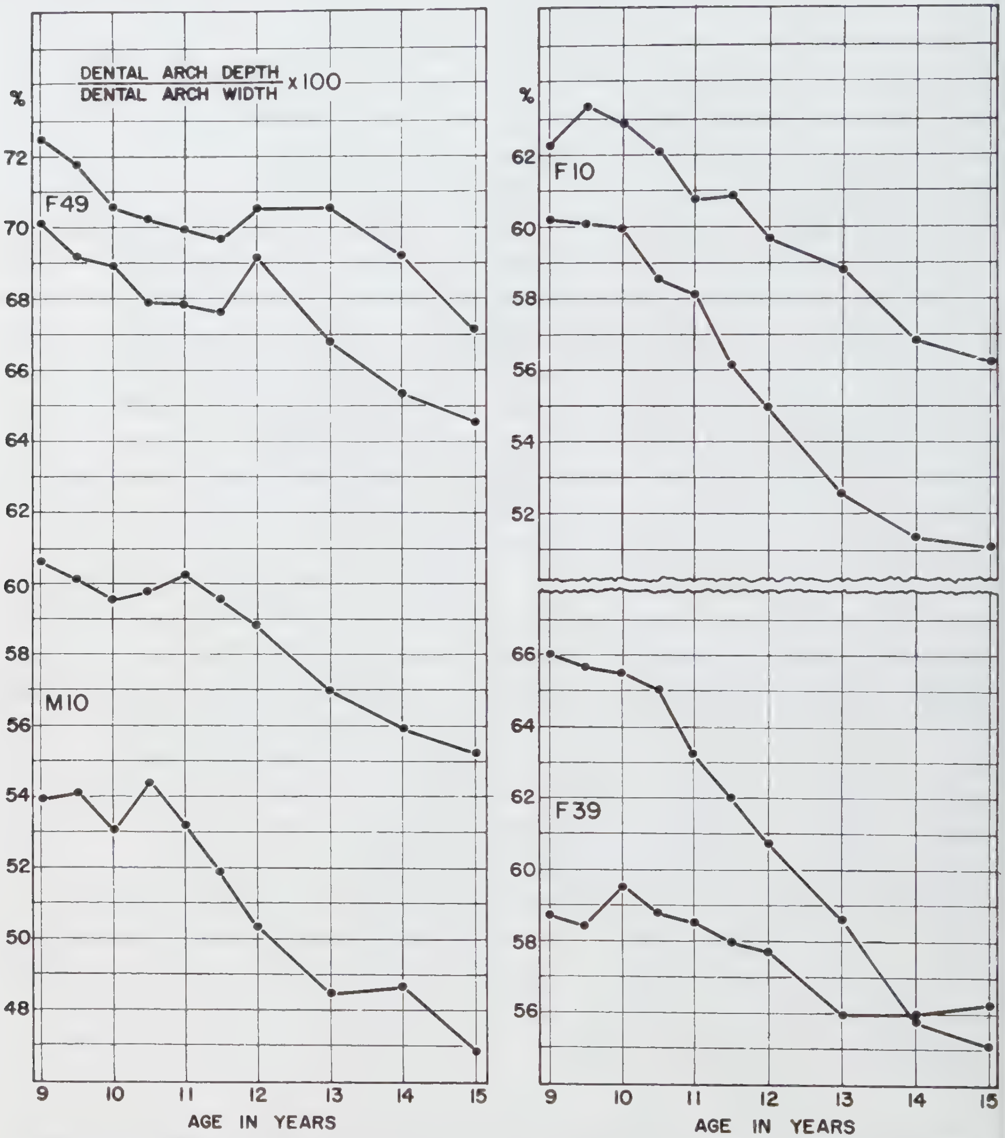


Fig. 6 Individual trends in maxillary and mandibular dental arch index. The left panel includes the subject with the relatively deepest arch (F49) and the subject with the relatively widest arch (M10) on the same scale. On the right, the top set of curves (F10) follow the pattern for the mean trend lines: at the bottom, one subject (F39) shows a reversal of the relation of the trend lines in the two arches until age 14 years.

TABLE 14

Correlation coefficients for indices of form of the dental arches

Index at: Years	9	11	13	15	Change: 9–15
Correlation between ages					
Upper arch					
9		0.96	0.88	0.90	−0.35
11			0.92	0.94	
13				0.95	
Lower arch					
9		0.88	0.89	0.87	−0.48
11			0.95	0.89	
13				0.95	
Correlation between arches					
	0.66	0.72	0.80	0.84	0.01

TABLE 15

Means and ranges of upper minus lower arch indices

Age	Mean		Minimum		Maximum	
	Males	Females	Males	Females	Males	Females
years						
9.0	3.8	1.6	−1.3	−7.3	7.1	6.2
11.0	4.7	3.8	0.6	−4.5	8.4	6.6
13.0	5.7	5.4	2.8	−2.7	8.5	10.8
15.0	5.7	5.4	3.4	1.1	8.4	10.0

The average magnitude and the individ- ıl variation in difference in the indices r the two arches are shown in table 15. ıe difference in the form of the two den- l arches increases from ages 9 years to years. The girls show a wider spread differences at all ages. For both sexes, e range of differences decreases with ge.

SUMMARY

Group and individual trends for maxil- ry and mandibular dental arch width ıd depth are presented for 29 children ith satisfactory occlusion.

The subjects, 16 boys and 13 girls, are hite children of American-born parents edominantly of northwest European an- stry and above average socio-economic atus. Sources for the dental arch meas- ements are casts made for each subject miannually between 9 years and 12 ars of age, and annually thereafter rough at least 15 years of age.

Arch width measurements are made from specified landmarks on the buccal surfaces of the permanent first molars. Arch depth is derived from three marked points: the two used in measuring arch width and an anterior point between the permanent central incisors. The ratio of the depth of the arch to its width (multiplied by 100) is computed to give indices of arch form.

Group statistics for the dimensions and indices are given in the form of means, standard deviations and ranges at 10 ages. For arch width and depth, individual findings are presented by means of annual changes for each subject and groupings of individual curves. Correlation coefficients of magnitude and change in the dimensions between ages and between maxillary and mandibular arches are included. Findings are compared to those of some previous investigations.

Between 9 years and 15 years of age, maxillary and mandibular arch width means increase over 2.0 mm for males and approximately 1.5 mm for females. Of the 58 individual curves for the two arches, over 60% show an increase over the first two to 5 years, followed by little or no change. Fourteen per cent of the curves show continued increase through at least 15 years of age, while an equal percentage show a total change from 9 years to 15 years of less than 1.0 mm. About 9% of the curves show some (near 1.0 mm) decrease in width over the later years.

There is a mean decrease in maxillary dental arch depth from 9 years to 15 years of 1.5 mm; this is composed of an increase of 0.4 mm to age 11 for males and age 10 years for females, and a subsequent decrease of 1.9 mm in each instance. The mean decrease in the mandibular arch depth is approximately 3.0 mm for both sexes. Between 12 years and 15 years, all individual curves on both arches show some decrease, ranging up to over 3.0 mm.

Depth of the upper arch is about 65% of the width at age 9 years and around 60% at age 15 years. In the lower arch, the change in the indices is somewhat greater.

LITERATURE CITED

Barrow, G. V., and J. R. White 1952 Developmental changes of the maxillary and mandibular dental arches. Angle Orthodontist, *22:* 41–46.

Brown, V. P., and I. Daugaard-Jensen 195 Change in the dentition from the early tee to the early twenties. Acta Odont. Scand., 177–192.

Cohen, J. T. 1940 Growth and development the dental arches in children. J. Am. Den Assoc., *27:* 1250–1260.

Goldstein, M. S., and F. L. Stanton 193 Changes in dimension and form of the dent arches with age. Internat. J. Orthodontia, 2 357–380.

Henriques, A. C. 1953 The growth of th palate and the growth of the face during th period of the changing dentition. Am. Orthodontics, *39:* 836–858.

Meredith, H. V., and G. C. Cox 1954 Wid of the dental arches at the permanent fir molars in children 9 years of age. Ibid., 4 134–144.

Moorrees, C. F. A. 1959 The Dentition of th Growing Child. Harvard University Press, Ca bridge, Massachusetts.

Rosander, A. C. 1951 Elementary Principles Statistics. D. Van Nostrand Company, Inc Toronto, New York, London.

Sillman, J. H. 1951 Serial study of good occl sion from birth to 12 years of age. Am. Orthodontics, *37:* 481–507.

——— 1956 Clinical consideration of occl sion. Ibid., *42:* 658–682.

Smyth, C., and M. Young 1932 Facial growt in children with special reference to dentitio Med. Res. Council, Spec. Rep. Series, No. 17

Speck, N. T. 1950 A longitudinal study developmental changes in human lower dent arches. Angle Orthodontist, *20:* 215–228.

Woods, G. A., Jr. 1950 Changes in width mensions between certain teeth and faci points during human growth. Am. J. Orth dontia, *36:* 676–700.

he Distribution of Chest Hair in Caucasoid Males

LAUREL RAYMOND SETTY
Department of Anatomy, Howard University College of Medicine,
Washington, D. C.

Danforth and Trotter ('22) considered o grades of pilosity in which the chest ir was the criterion: grade 1, hair in the nter of the chest or about the nipples; ade 2, considerable area of hair on the est and breasts. Miller ('31) accounted r human hair patterning in general as tendency imposed by primate heritage. upertuis, Atkinson and Elftman ('45) assified chest hair simply as sparse and nspicuous. Because of the limited treatent, heretofore, of the distribution of e hair of the chest, the present study was ndertaken.

METHOD

The subjects observed were stripped en in the shower rooms of public swiming pools in and near the District of lumbia. Selection was limited to adult, esomorphic Caucasoids; but these were ken at random.

The chest hair distribution and abdomil hair pattern were determined without e awareness of the subject. The age was timated in the same way or obtained rbally from the subject during a conrsation. These data were recorded imediately after their determination and fore another subject was considered.

RESULTS

Ten different types of distribution of est hair (figs. 1 and 2) were recognized the basis of the specific part or parts the chest in which the more noticeable ir occurred.[1] These types are briefly deribed as follows:

1. *Sternal.* Hair on the center or the wer part of the area occupied by the body the sternum.
2. *Infraclavicular.* Hair on the area mediately below the medial end of the avicle and extending or not extending erad therefrom.
3. *Pectoral.* Hair on the breast (including the area immediately around the areola).
4. *Pecto-sternal.* Hair on the pectoral and the sternal regions with no line of demarcation between them.
5. *Pecto-infraclavicular.* Hair on the pectoral, and infraclavicular areas, connected or not connected by a narrow strip of hair.
6. *Pecto-sterno-infraclavicular.* Hair on the pectoral, sternal and infraclavicular regions with no line of demarcation between any two of them.
7. *Circumareolar.* Hair limited to a small area immediately encircling the areola.
8. *Circumareolo-sternal.* Hair on two separate areas, namely, circumareolar and sternal.
9. *Circumareolo-infraclavicular.* Hair on two separate areas, namely circumareolar and infraclavicular.
10. *Circumareolo-sterno-infraclavicular.* Hair distributed as in the circumareolo-infraclavicular, but with an extension of the hair into the sternal region with or without some demarcation.

The first 6 of the types listed above may be called the pecto-sterno-infraclavicular series since they are distributed in all or some of the regions indicated. In addition, the remaining 4 types may be termed the circumareolar series because they are found entirely or in part in the circumareolar area.

The age range and the frequency of occurrence for each of the 10 patterns of chest hair distribution are summarized in

---

[1] In forming a compound name, the name of the area that occurs on both the right and the left sides of the body is used for the first part of the word. When there are two unpaired areas, the one with the shorter name is placed in front of the one with the longer name.

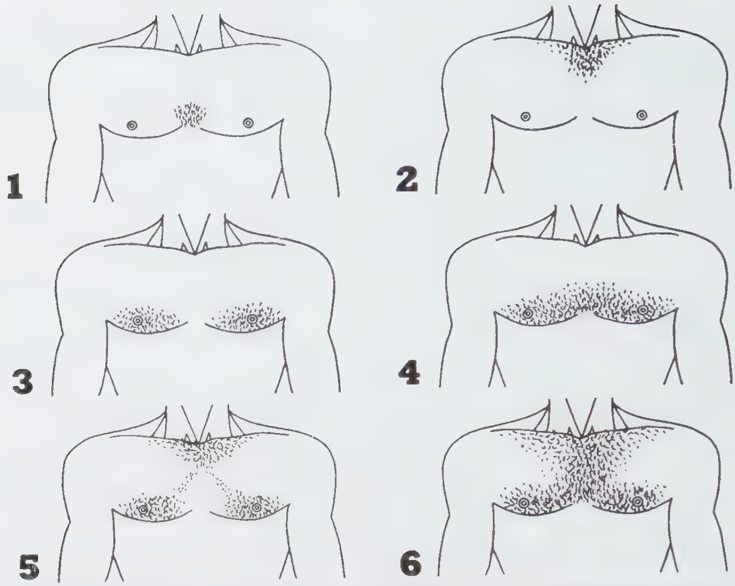


Fig. 1 Types of distribution of chest hair (pecto-sterno-infraclavicular series). 1, Sternal; 2, infraclavicular; 3, pectoral; 4, pecto-sternal; 5, pecto-infraclavicular; 6, pecto-sterno-infraclavicular.

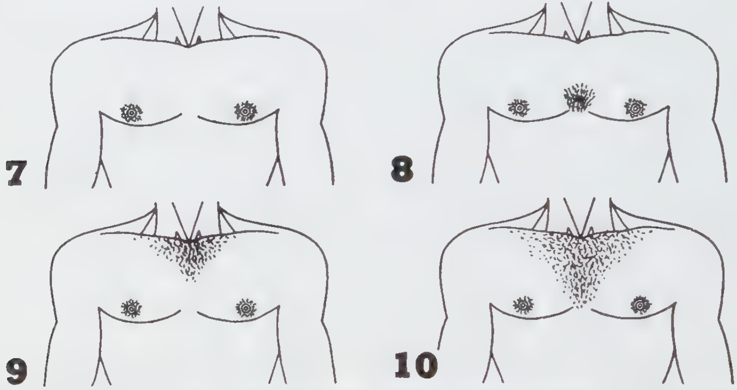


Fig. 2 Types of distribution of chest hair (circumareolar series). 7, Circumareolar; 8, circumareolo-sternal; 9, circumareolo-infraclavicular; 10, circumareolo-sterno-infraclavicular.

TABLE 1

Age range and incidence of the different types of distribution of chest hair

Type	Age range	Incidence
	year	%
Sternal	18–63	4
Infraclavicular	25–30[1]	1
Pectoral	37–66	6
Pecto-sternal	25–71	16
Pecto-infraclavicular	29–45	1
Pecto-sterno-infraclavicular	17–67	51
Circumareolar	18–50	9
Circumareolo-sternal	18–41	8
Circumareolo-infraclavicular	21–28[1]	2
Circumareolo-sterno-infraclavicular	21–22	1

[1] Age ranges were estimated. All age ranges are inclusive.

TABLE 2

Correlation of kinds of chest hair patterns and types of abdominal hair patterns

	Horizontal	Sagittal	Acuminate	Disperse
Sternal	—	1	12	—
Infraclavicular	—	–	2	1
Pectoral	—	–	8	11
Pecto-sternal	—	–	25	26
Pecto-infraclavicular	—	–	2	1
Pecto-sterno-infraclavicular	—	–	82	75
Circumareolar	3	–	17	8
Circumareolo-sternal	2	1	21	2
Circumareolo-infraclavicular	2	–	4	1
Circumareolo-sterno-infraclavicular	—	–	3	—
Apilose	15[1]	3	12	—

[1] Age range for the 15 individuals of this combination is 24 through 65 years.

le 1. A total of 310 subjects with chest ir was observed.

Dupertuis, Atkinson and Elftman ('45) de known 4 types of abdominal hair terns: (1) horizontal, characterized by minating superiorly in the pubic region a horizontal line; (2) sagittal, similar the horizontal, except for an additional ear upward extension in the mid-line;) acuminate, an upward triangular ex- sion pointing towards the umbilicus; d (4) disperse, hair distributed over the lomen without forming a discrete geo- trical pattern.

The relation of the kinds of chest hair terns to the types of abdominal hair terns is shown for 340 subjects in le 2.

SUMMARY

n addition to apilose chests, 10 differ- types of distribution of chest hair exist adult, Caucasoid males. These types y be termed sternal, infraclavicular, pectoral, pecto-sternal, pecto-infraclavicular, pecto-sterno-infraclavicular, circumareolar, circumareolo-sternal, circumareolo-infraclavicular and circumareolo-sterno-infraclavicular.

The majority of the chest hair patterns is found in individuals of a wide age range. The same is true of apilosity of the chest.

The pecto-sterno-infraclavicular type of chest hair distribution has an incidence of over 50%. All of the types are found to occur in combination with the acuminate type of abdominal hair pattern.

LITERATURE CITED

Danforth, C. H., and M. Trotter 1922 The distribution of body hair in white subjects. Am. J. Phys., Anthrop., *5:* 259–265.

Dupertuis, C. W., W. B. Atkinson and H. Elftman 1945 Sex differences in pubic hair distribution. Human Biol., *17:* 137–142.

Miller, G. S. 1931 Human hair and primate patterning. Smithsonian Misc. Coll., *85:* 1–13.

rowth and Skeletal Maturation of Chinese hildren in Hong Kong

S. T. CHAN, K. S. F. CHANG AND F. K. HSU
Department of Anatomy, University of Hong Kong, Hong Kong

The developmental status of the skel- on as disclosed by an x-ray film of the nd and wrist, supplemented by signifi- nt physical measurements, appear to be e most useful and reliable procedure that at present available for evaluating phys- al growth and development of children. mong the various methods so far devised r the assessment of skeletal maturation Pryor, '05; Rotch, '08, '09, '10; Rotch nd Smith, '10; Baldwin, '21; Flory, '36; elly, '37; Todd, '37; Greulich and Pyle, 0, '58; Acheson, '54), that of Todd and s associates, Greulich and Pyle, the so- lled inspectional method, is still the most mmonly chosen.

In reviewing literature relevant to the owth and development of the Chinese, e note an absence of any reference to eletal maturation in all of the past stud- s (Crook, '08; Shirokogoroff and Apple- n, '24; Stevenson, '25; Keys and Cad- ry, '26; Appleton, '28). This is not rprising, however, because these studies ere made before the method of skeletal aturation was standardized and intro- ced by Todd and his colleagues. It is ith the special interest of obtaining some ta on this aspect of growth and develop- ent of the Chinese that the present in- stigation has been carried out.

SUBJECTS AND METHOD

The subjects studied were selected from e outpatient clinics of Kowloon and wong Wah Hospitals in Hong Kong from 58 to 1960. All of them possessed althy past histories and examinations vealed no gross defects physically and entally. They came to the clinics on count of mild illnesses. Date of birth, ace of birth and family financial status ere recorded. The chronological ages ere calculated by counting back from the dates they were examined to their birthdays which were obtained either from their parents or from their identity cards.

A P-A roentgenogram of left hand and wrist, including the distal ends of radius and ulna, and the standing height and body weight of each child were made. The skeletal maturation was assessed by two observers by comparing the x-ray films of the hands carefully with the standards illustrated in both Todd's Atlas ('37) and Greulich and Pyle's Atlas ('50, '58). The roentgenograms were examined in a completely random manner by the two observers working independently.

In order to compare the roentgenograms of our children with Todd's standards which were obtained from boys of three months to 18 years and 9 months of age, and from girls of three months to 16 years and three months of age, we were obliged to limit our skeletal studies to the corresponding age groups, and this slightly reduced the number at our disposal to 262 children, consisting of 148 boys and 114 girls. Our height and weight studies, however, were extended to the age of 20 and a total of 151 boys and 136 girls were examined.

The skeletal age was determined for each subject by the mean of the two assessments of the two observers. Comparisons between Chinese and Cleveland boys and girls of the Brush Foundation were made and the variance analysis between the two observers and the two atlases has been calculated.

The majority of the children in this study were born in Kwangtung Province and in Hong Kong, and more than half of them were brought up from families of rather poor circumstances which represent unfortunately the majority of the Hong Kong population.

TABLE 1

Average standing height (inches)

Boys				Girls			
Age group	Chinese		U.S.A. Brush Foundation Study	Age group	Chinese		U.S.A. Brush Foundatio Study
years	*no.*			*years*	*no.*		
0 (0.64)[1]	7	24.93	—	0 (0.56)[1]	10	25.48	—
1 (1.25)	10	29.10	—	1 (1.56)	7	30.89	—
2 (2.62)	6	33.38	—	2 (2.41)	6	30.17	—
3 (3.32)	8	35.22	—	3 (3.47)	4	35.75	—
4 (4.54)	8	38.72	—	4 (4.33)	5	38.55	—
5 (5.65)	9	40.86	—	5 (5.32)	7	40.43	—
6 (6.66)	5	41.20	46.34	6 (6.55)	5	44.90	46.30
7 (7.46)	10	45.93	48.74	7 (7.50)	13	44.58	48.74
8 (8.58)	6	50.08	51.14	8 (8.37)	6	46.54	51.10
9 (9.45)	11	49.89	53.31	9 (9.49)	7	53.82	53.27
10 (10.57)	6	51.54	55.51	10 (10.44)	5	49.40	55.51
11 (11.52)	13	53.56	57.44	11 (11.79)	6	52.92	58.15
12 (12.77)	10	58.23	59.61	12 (12.54)	7	57.82	60.71
13 (13.62)	9	56.97	62.01	13 (13.28)	4	57.69	62.79
14 (14.30)	6	60.21	64.88	14 (14.59)	8	59.44	64.13
15 (15.61)	6	61.17	67.36	15 (15.43)	8	62.75	64.89
16 (16.49)	5	63.30	68.98	16 (16.51)	6	62.21	65.16
17 (17.69)	7	65.14	69.57	17 (17.47)	11	63.27	65.12
18 (18.47)	5	65.00	—	18 (18.69)	8	61.41	—
19 (19.48)	4	64.69	—	19 (19.56)	3	61.23	—

[1] The figures in parentheses are the mean chronological ages of the age groups of the present stud

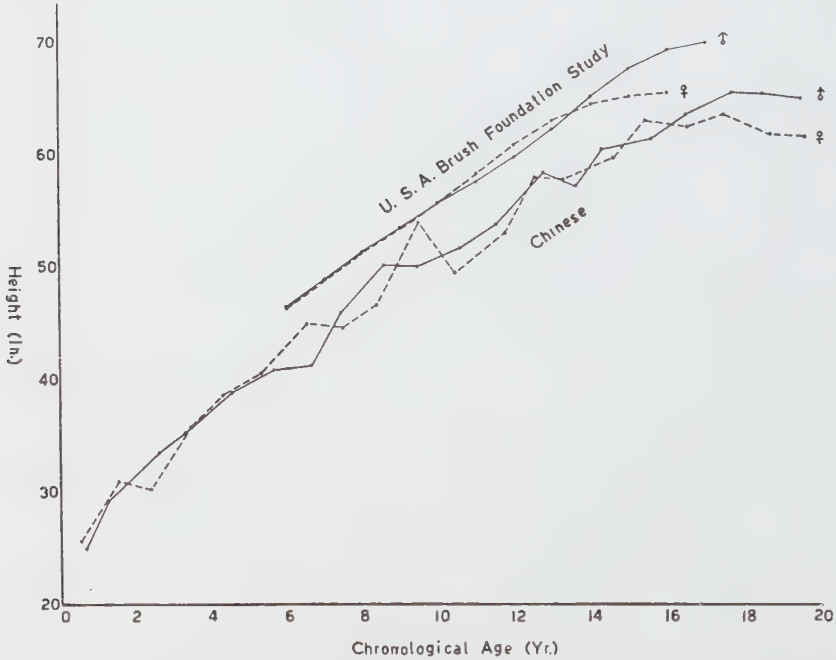


Fig. 1 Standing height of boys and girls in relation to chronological age. Heights of the Cleveland boys and girls of the Brush Foundation Study are shown for comparison.

RESULTS

Average standing height

The average standing heights of the oys and girls of our series at each age om three months to 20 years are listed table 1. The corresponding values of e Cleveland children of the Brush Foundation Study are presented in the same ble for comparison. They are also shown aphically in figure 1.

From table 1 and figure 1, it is apparent at the average standing height of Chiese children in our series is significantly wer than that of the Cleveland children the Brush Foundation Study. The disnce curves in the stature of both our oys and girls are rather variable. Up to th year the difference between boys and rls is not significant; thereafter, the boys e taller than the girls.

Average weight

The average body weights of the Chiese children at each age from three onths to 20 years and of the Cleveland ildren are listed in table 2 and presented aphically in figure 2.

From both the table and the graph, it can be seen that the average weight of the children of our series is distinctly less than that of the Cleveland children in both sexes throughout all ages. The difference increases as age advances.

The average weight of the Cleveland girls exceeds that of the Cleveland boys during the period from 8 to 14 years of age. This feature is not demonstrated in our data which show dovetailing irregularities but on account of the small size of our samples, we are not in a position to make a definite statement. After the age of 16 the boys are heavier than the girls.

Weight-height index

The weight-height index, Weight in ounces/Height in inches, is a useful indicator of the nutritional status by a comparison of the weight per unit of height. A comparison of the weight-height indices of Chinese and Cleveland children is shown in table 3.

Whyte ('18) found in his study that the weight-height index of the male Southern Chinese adults varied between 26–30 oz. per inch and that of adult females was

TABLE 2

Average body weight (lbs.)

Boys				Girls			
Age group		Chinese	U.S.A. Brush Foundation Study	Age group		Chinese	U.S.A. Brush Foundation Study
years	*no.*			*years*	*no.*		
(0.64)[1]	7	16.00	—	0 (0.56)[1]	10	13.90	—
(1.25)	10	19.58	—	1 (1.56)	7	21.86	—
(2.62)	6	26.67	—	2 (2.41)	6	23.67	—
(3.32)	8	27.13	—	3 (3.47)	4	32.50	—
(4.54)	8	33.50	—	4 (4.33)	5	33.40	—
(5.65)	9	36.22	—	5 (5.32)	7	35.00	—
(6.66)	5	34.60	48.18	6 (6.55)	5	44.20	48.18
(7.46)	10	46.20	54.12	7 (7.50)	13	39.46	54.34
(8.58)	6	50.00	61.60	8 (8.37)	6	42.58	61.82
(9.45)	11	51.09	68.20	9 (9.49)	7	52.86	69.52
(10.57)	6	59.67	76.78	10 (10.44)	5	52.40	77.88
(11.52)	13	62.38	85.36	11 (11.79)	6	64.00	88.22
(12.77)	10	75.80	95.04	12 (12.54)	7	77.71	100.32
(13.62)	9	77.78	105.38	13 (13.28)	4	70.25	110.22
(14.30)	6	83.17	118.80	14 (14.59)	8	81.63	119.90
(15.61)	6	90.00	132.00	15 (15.43)	8	94.25	126.28
(16.49)	5	102.20	141.68	16 (16.51)	6	93.33	129.58
(17.69)	7	105.14	147.18	17 (17.47)	11	104.59	133.98
(18.47)	5	108.40	—	18 (18.69)	8	96.13	—
(19.48)	4	117.75	—	19 (19.56)	3	96.33	—

[1] The figures in parentheses are the mean chronological ages of the age groups of the present study.

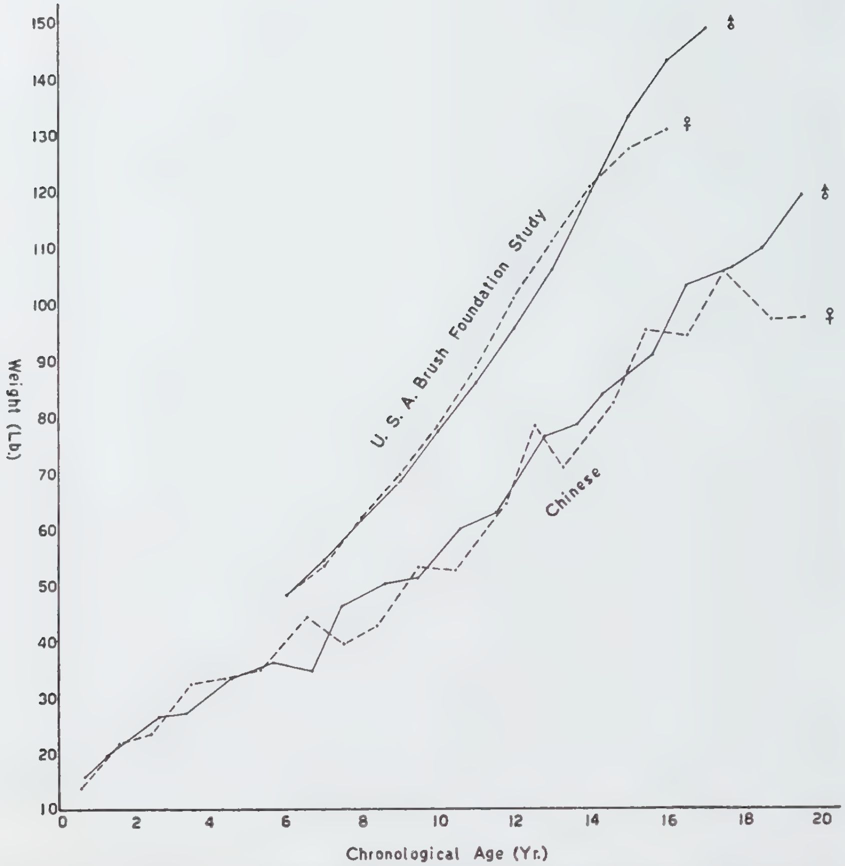


Fig. 2 Body weight of boys and girls in relation to chronological age. Weights of Cleveland boys and girls of the Brush Foundation Study are shown for comparison.

TABLE 3

Weight-height index

Age group	Boys		Girls	
	Chinese	U.S.A. Brush Foundation Study	Chinese	U.S.A. Brush Foundation Study
years				
0	10.27	—	8.73	—
1	10.77	—	11.32	—
2	12.78	—	12.55	—
3	12.32	—	14.55	—
4	13.84	—	13.86	—
5	14.18	—	13.85	—
6	13.44	16.64	15.75	16.65
7	16.09	17.77	14.16	17.84
8	15.97	19.27	14.64	19.36
9	16.38	20.47	15.71	20.88
10	18.52	22.13	16.97	22.45
11	18.63	23.78	19.35	24.27
12	20.83	25.51	21.50	26.44
13	21.84	27.19	19.48	28.09
14	22.10	29.30	21.97	29.91
15	23.54	31.35	24.03	31.14
16	25.83	32.86	24.00	31.82
17	25.82	33.85	26.45	32.92
18	26.68	—	25.05	—
19	29.12	—	25.17	—

oz. per inch. Our findings for males nd females of 19 to 20 years old are 9.12 and 25.17 oz. respectively.

By comparison with the Cleveland chilren, the weight-height indices of Chinese hildren of our series are less at every age. his would appear to indicate that the utritional status of the children of our eries is below par.

Skeletal age

Skeletal ages were assessed by comparng x-ray films of the hands and wrists ith both Todd's standard and Greulich and Pyle's standard by two observers H. and C., once for each subject.

The mean estimated skeletal ages of Chinese boys and girls, together with their corresponding mean chronological ages are shown in table 4.

The correlation between skeletal age and chronological age of Chinese boys was calculated and presented graphically in figure 3 by the regression equations $Y = 0.99X - 0.97$ (by Greulich and Pyle's standard) and $Y = 1.01X - 0.99$ (by Todd's standard); and that of girls in figure 4 by the regression equations $Y = 0.97X - 0.60$

TABLE 4

Mean chronological and skeletal ages of Chinese boys and girls

ge oup	No.	Mean chr. age	Mean estimated skeletal ages (years)					
			Greulich and Pyle's standard			Todd's standard		
			Observer H	Observer C	Both Observers	Observer H	Observer C	Both Observers
ars		*years*						
			Boys					
0–1	7	0.64	0.65	0.62	0.63	0.64	0.64	0.64
1–2	10	1.25	1.08	1.11	1.09	1.05	1.03	1.04
2–3	5	2.58	2.30	2.40	2.35	2.30	2.45	2.37
3–4	8	3.32	2.33	2.39	2.36	2.28	2.31	2.29
4–5	9	4.54	3.18	3.28	3.23	3.14	3.25	3.19
5–6	9	5.65	3.83	4.19	4.01	4.10	4.25	4.17
6–7	5	6.66	4.70	4.40	4.55	4.62	4.80	4.71
7–8	10	7.46	6.18	6.30	6.24	6.43	6.60	6.51
8–9	6	8.58	7.00	6.92	6.96	7.04	7.25	7.14
9–10	11	9.45	7.70	7.67	7.68	7.77	7.93	7.85
0–11	7	10.50	8.41	8.71	8.56	8.82	8.93	8.87
1–12	13	11.52	9.82	10.13	9.97	10.29	10.27	10.28
2–13	9	12.78	12.19	12.92	12.55	12.72	13.22	12.97
3–14	10	13.62	12.59	12.53	12.56	12.66	12.88	12.77
4–15	6	14.30	13.33	13.42	13.37	13.58	13.88	13.73
5–16	6	15.61	15.18	14.92	15.05	15.35	15.33	15.34
6–17	5	16.49	15.05	15.10	15.07	15.17	15.25	15.21
7–18	7	17.69	17.68	17.71	17.69	17.61	17.86	17.73
8–19	5	18.47	17.32	17.45	17.38	17.42	17.50	17.46
otal	148	9.22	8.10	8.21	8.16	8.25	8.39	8.32
			Girls					
0–1	10	0.56	0.53	0.60	0.56	0.45	0.45	0.45
1–2	7	1.56	1.54	1.58	1.56	1.36	1.33	1.34
2–3	8	2.32	1.75	1.82	1.78	1.66	1.69	1.67
3–4	5	3.41	2.42	2.42	2.42	2.20	2.25	2.22
4–5	6	4.44	3.01	3.13	3.07	3.33	3.54	3.43
5–6	8	5.33	4.17	4.19	4.18	4.27	4.50	4.38
6–7	5	6.55	5.57	5.65	5.61	5.87	5.90	5.88
7–8	13	7.50	6.07	6.17	6.12	6.31	6.64	6.47
8–9	6	8.37	6.86	6.92	6.89	6.92	7.04	6.98
9–10	7	9.49	8.62	8.56	8.59	8.84	8.79	8.81
0–11	5	10.44	8.48	8.10	8.29	8.30	8.25	8.27
1–12	6	11.67	10.56	10.92	10.74	10.83	10.88	10.85
2–13	7	12.54	12.46	12.71	12.58	12.87	13.07	12.97
3–14	5	13.27	12.72	12.70	12.71	12.80	13.07	12.93
4–15	9	14.63	13.38	13.42	13.40	13.47	13.47	13.47
5–16	7	15.36	15.11	15.36	15.23	15.08	15.21	15.14
otal	114	7.75	6.88	6.95	6.92	6.97	7.08	7.03

(by Greulich and Pyle's standard) and Y = 0.99X − 0.65 (by Todd's standard). The U.S.A. standard is included in the same figures for comparison.

For the comparison of the skeletal ages of Chinese boys and girls, the regression line and equation for boys Y = 0.99X − 0.97 and that for girls Y = 0.97X − 0.60 are shown in figure 5.

From the tables and graphs, it is clear that the skeletal ages of both Chinese boys and girls are less than that of the Cleveland children at every age with a mean difference of 1.06 years with Greulich and Pyle's standard, and 0.90 year with Todd's standard, the average difference being therefore 0.98 year for the Chinese boys. In girls, the difference is 0.83 with Greulich and Pyle's standard and 0.72 year with Todd's standard, the average difference being 0.78 year. Our finding shows, therefore, that the skeletal ages of the children of our series are "retarded" by about 12 months in boys and 9 months in girls as compared with the American children.

From table 4, it can be noted that the data from the two observers and according to the two atlases differ from each other. However, variance analysis show these differences to be more apparent than real.

DISCUSSION

It will be both interesting and necessary to compare the findings of our series with those of previous investigators, which we present in tables 5 and 6, and graphically in figures 6 and 7. As noted before, skeletal maturation has not been studied before in the Chinese.

Crook's samples ('08) were boy students of Queen's College in Hong Kong whose ages ranged from 10 to 24 and

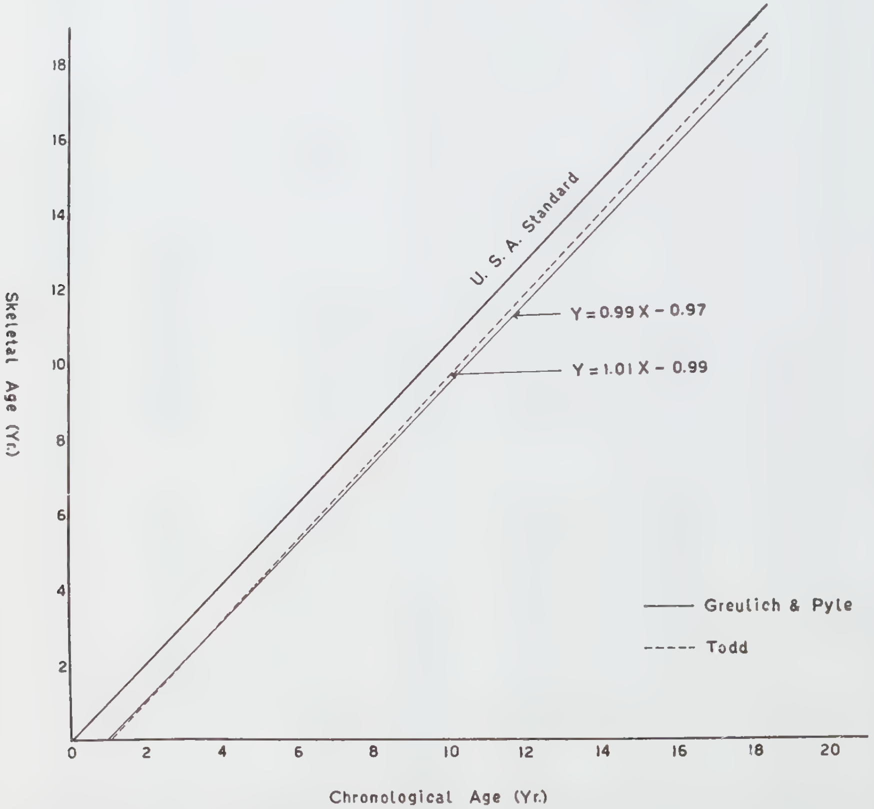


Fig. 3 Correlation of the skeletal age with the chronological age of boys, based on Greulich and Pyle's and Todd's standards. U.S.A. standard is shown for comparison.

udging by the school they attended and he results of their measurements, it is easonable to presume that they came rom homes of high socio-economic level. hirokogoroff and Appleton ('24) drew heir samples from the general population f Chekiang, Fukien, Kiangsu, Shansi and unan, i.e., South and Central China. The art of Stevenson's data ('25) relevant to ur study was collected from the general opulation of South China, namely Kwangung, Fukien, Kwangsi, Yunan and Kweihow, but mainly from Kwangtung. Keys nd Cadbury ('26) obtained their samples rom the student body of the then Canton hristian College, later known as Lingnan iddle School and Lingnan University, wangtung; they were sons of wealthy erchants and a few were oversea Chiese. An examination of figures 6 and 7 hows interestingly that the samples rawn by these various workers agree in general with each other and that our samples, though small and restricted, accord well with theirs. However, one feature worthy of note is that the usual secular trend in the gradual increase of stature, so commonly observed in most other countries, is not indicated in our series in spite of a span of more than 30 years between these earlier works and our investigation. This would imply either that socio-economic conditions have shown no improvement or even deterioration for the majority of the population of Hong Kong or that our samples are not sufficiently representative. Either or both could be the case, for while social betterment is generally apparent, it is suggestive that such a condition could not have reached as yet the majority of the teeming masses who congest Hong Kong to benefit their welfare in any significant manner; and on the other hand, it is admittedly true that our

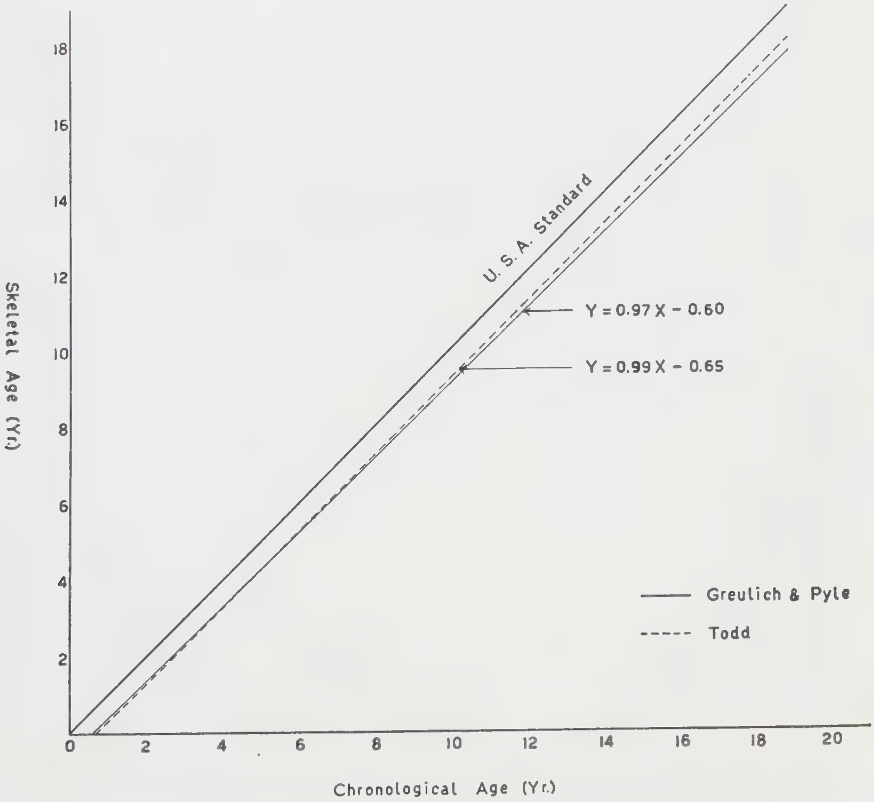


Fig. 4 Correlation of the skeletal age with the chronological age of girls, based on the Greulich and Pyle's and Todd's standards. U.S.A. standard is shown for comparison.

sampling does not include a sufficient number of families which could be considered as well-to-do.

Compared with the Brush Foundation children, our data and those of others show a common feature of "retardation." There would seem little doubt that this phenomenon is intimately related to the nutritional status and environmental conditions, whose significant effects on growth have been abundantly shown by various authors, such as Francis ('39), Greulich ('51, '57), Clements ('53) and many others and reviewed by Palmer and Ciocco ('41), and Stuart ('46). Pertinent to our study in particular, especially revealing are the comparative studies of Southern Chinese in China and Southern Chinese immigrants into Hawaii and America with Hawaiian-born and American-born Southern Chinese (Appleton, '28; Lasker, '46). To mention one obvious fact, polished rice, which is less nutritious than bread, is the staple food of Southern Chinese, and compared with western peoples, Chinese consume less milk as a supplementary food. In addition, the climate of South China is warm and humid, and this is likely to effect or modify bodily dimensions and growth. In short, this general feature of retardation may be regarded biologically as a phenotypical expression of ecologica effects either in terms of frank consequence or as adaptive responses or modifications. On the other hand, the operation of these extrinsic factors cannot exclude the possibility, or indeed the importance of the intrinsic genetic factors in the role they play in qualifying the pattern of growth and developmental potential, characteristic of the population or what we would generally refer to as the "race." These and other aspects present interesting problems which we intend to pursue

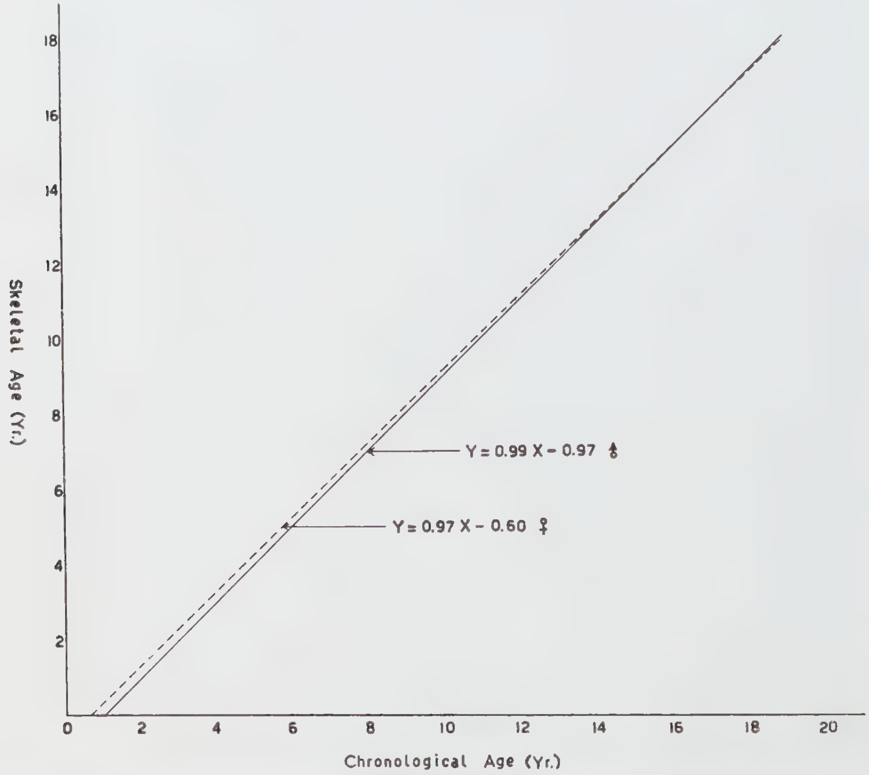


Fig. 5 Comparison of the skeletal age of boys with that of girls. Estimation by Greulich and Pyle's standard.

TABLE 5

Comparison of height and weight of Chinese boys of our series with those of previous investigators

Age group	Height (in.)										Weight (lbs.)									
	Crook, '08		Shirok. and Appleton, '24		Stevenson, '25		Keys and Cadbury, '26		Present study, '60		Crook, '08		Shirok. and Appleton, '24		Stevenson, '25		Keys and Cadbury, '26		Present study, '60	
	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean
years																				
0		—		—		—		—	7	24.93		—		—		—		—	7	16.00
1		—		—		—		—	10	29.10		—		—		—		—	10	19.58
2		—		—		—		—	6	33.38		—		—		—		—	6	26.67
3		—	36	33.66		—		—	8	35.22		—	34	27.07		—		—	8	27.13
4		—	33	36.80		—		—	8	38.72		—	30	31.05		—		—	8	33.50
5		—	41	38.42	2	40.51		—	9	40.86		—	41	34.21	2	32.78		—	9	36.22
6		—	47	41.65	5	46.18		—	5	41.20		—	47	37.45	5	44.00		—	5	34.60
7		—	48	43.82	15	47.52	29	45.84	10	45.93		—	48	40.04	15	41.58	29	43.85	10	46.20
8		—	81	45.32	23	48.74	51	47.29	6	50.08		—	81	44.41	23	48.84	51	47.61	6	50.00
9		—	63	47.81	28	48.94	64	49.30	11	49.89		—	63	49.30	29	49.06	64	52.19	11	51.09
10	3	54.1	87	50.20	34	51.18	71	50.98	6	51.54	3	64.2	87	54.50	34	53.68	71	56.62	6	59.67
11	6	54.0	83	52.47	61	53.07	74	52.75	13	53.56	6	66.2	83	59.65	68	58.30	74	61.40	13	62.38
12	15	56.0	66	54.17	55	54.72	85	54.77	10	58.23	15	73.6	66	63.60	58	64.02	85	68.12	10	75.80
13	27	59.6	59	56.42	84	56.34	89	57.29	9	56.97	27	78.7	59	72.18	85	71.06	89	77.41	9	77.78
14	55	62.2	47	57.62	148	58.94	96	60.02	6	60.21	55	90.9	47	77.55	138	78.10	96	88.50	6	83.17
15	95	62.9	28	60.59	200	59.41	99	62.26	6	61.17	95	97.6	28	91.26	187	88.22	99	98.90	6	90.00
16	133	63.5	31	62.02	240	62.32	91	63.79	5	63.30	133	101.6	31	99.39	222	93.94	91	106.74	5	102.20
17	112	64.2	27	62.26	203	63.66	91	64.53	7	65.14	112	106.0	27	109.47	209	103.62	91	110.86	7	105.14
18	98	64.0	43	63.41	206	63.98	81	65.02	5	65.00	98	108.9	43	107.44	198	106.04	81	114.17	5	108.40
19	63	65.7	33	63.56	188	64.64	56	65.26	4	64.69	63	114.4	33	113.28	179	111.54	56	116.34	4	117.75
20	34	65.6	17	64.31	80	64.80	36	65.26		—	34	113.4	19	113.57	80	111.98	36	116.34		—

TABLE 6

Comparison of height and weight of Chinese girls of our series with those of previous investigator

Age group	Height (in.)						Weight (lbs.)					
	Shirok. and Appleton, '24		Stevenson, '25		Present study, '60		Shirok. and Appleton, '24		Stevenson, '25		Present study, '60	
	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean	No.	Mean
years												
0		—		—	10	25.48		—		—	10	13.90
1		—		—	7	30.89		—		—	7	21.86
2		—		—	6	30.17		—		—	6	23.67
3	20	33.01		—	4	35.75	19	25.23		—	4	32.50
4	16	35.98		—	5	38.55	16	29.55		—	5	33.40
5	31	37.61	1	41.14	7	40.43	31	30.65	1	36.52	7	35.00
6	18	40.69	4	45.00	5	44.90	18	35.51	4	37.84	5	44.20
7	20	42.09	4	46.61	13	44.58	20	37.47	4	49.06	13	39.46
8	9	43.82	10	47.68	6	46.54	9	40.66	10	44.88	6	42.58
9	18	45.66	6	49.68	7	53.82	18	44.95	6	48.40	7	52.86
10	18	48.35	11	54.41	5	49.40	18	49.36	11	54.78	5	52.40
11	22	49.69	48	52.20	6	52.92	22	54.10	48	58.52	6	64.00
12	22	53.40	60	53.86	7	57.82	22	61.65	59	66.44	7	77.71
13	22	55.27	66	55.83	4	57.69	22	68.34	66	73.70	4	70.25
14	17	57.27	51	56.89	8	59.44	17	77.48	51	80.52	8	81.63
15	11	59.22	58	59.37	8	62.75	11	86.88	57	88.88	8	94.25
16	11	58.92	56	58.19	6	62.21	11	91.63	55	90.42	6	93.33
17	6	59.95	57	60.00	11	63.27	6	91.66	57	97.24	11	104.59
18	5	58.13	41	59.68	8	61.41	5	91.40	41	99.44	8	96.13
19		—	21	59.84	3	61.23		—	20	97.68	3	96.33
20		—		—		—		—		—		—

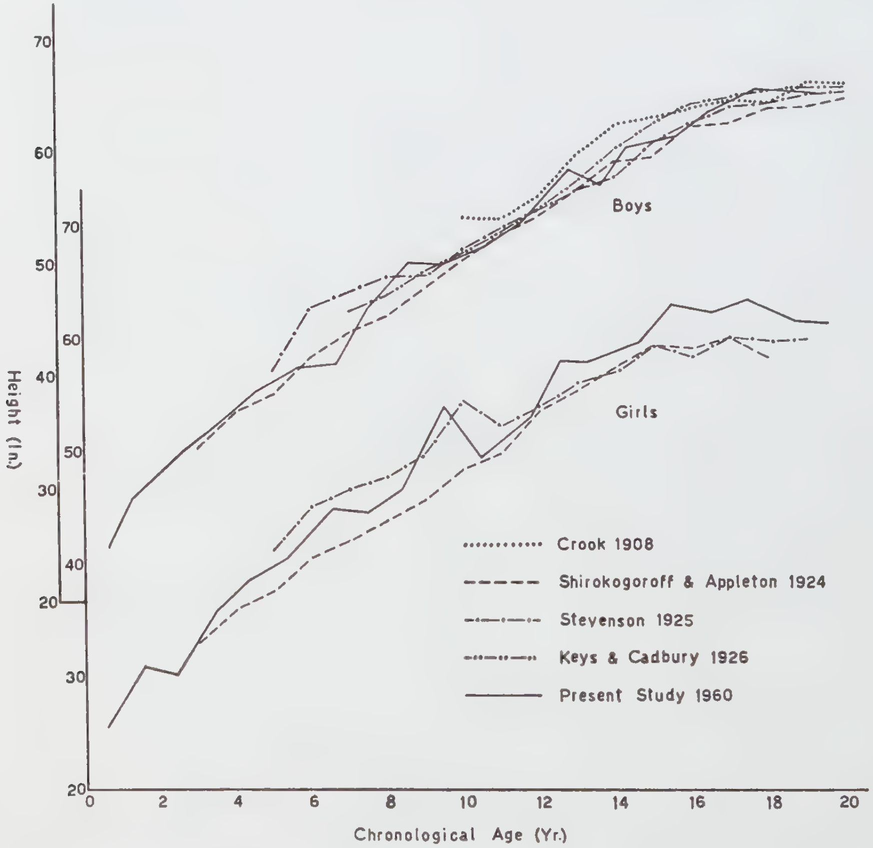


Fig. 6 Comparison of height of Southern Chinese children of previous studies with that of the present study.

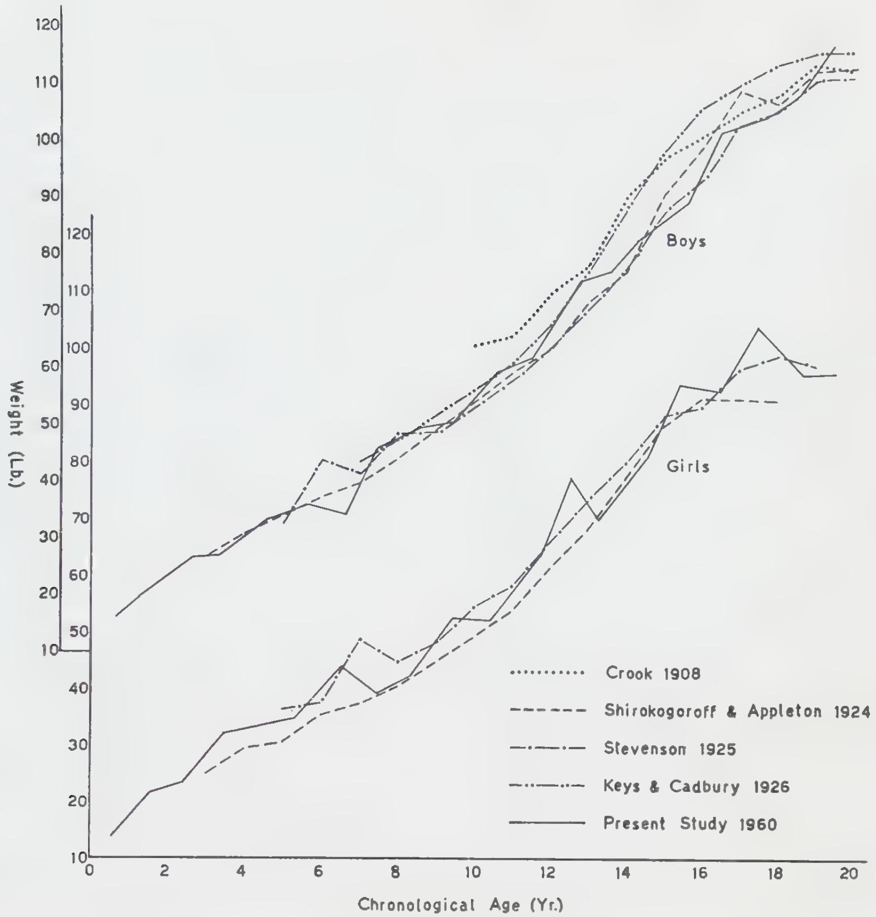


Fig. 7 Comparison of weight of Southern Chinese children of previous studies with that of the present study.

SUMMARY

The standing height and weight of 287 Chinese boys and girls from three months to 20 years old were taken, and among them, assessment of skeletal maturation was made for 148 boys and 114 girls according to Todd's and Greulich and Pyle's standards, the boys' ages ranging from three months to 18 years and 9 months, and the girls' ages from three months to 16 years. The findings of the present study have been compared with the previous studies on the growth of the Chinese based on height and weight, and with those of the Brush Foundation Study. The standing heights, body weights, and the weight-height indices of the children of the present study are less at all ages than the Cleveland children; and the skeletal ages have been found to be delayed by an average of 12 months in boys and 9 months in girls. The significance of these findings are briefly discussed.

ACKNOWLEDGMENT

We would like to record our great indebtedness to Dr. Alan Chan of Kowloon Hospital for his invaluable, in fact, indispensable assistance in this research.

LITERATURE CITED

Acheson, R. M. 1954 A method of assessing skeletal maturity from radiographs: A report from the Oxford Child Health Survey. J. Anat., *88:* 498–508.

Appleton, V. B. 1928 Growth of Kwangtung Chinese in Hawaii. Am. J. Phys. Anthrop., *11:* 473–500.

Baldwin, B. T. 1921 The physical growth of children from birth to maturity. Univ. Iowa Stud. Child Welf., *1:* no. 1.

Clements, E. M. B. 1953 Changes in the mean stature and weight of British children over the past seventy years. Brit. Med. J., *2:* 897–902.

Crook, A. H. 1908 Measurements of the Chinese. Nature, *78:* 607.

Flory, C. D. 1936 Osseous development in the hand as an index of skeletal development. Monogr. Soc. Res. Child Dev., *1:* no. 3.

Francis, C. C. 1939 Factors influencing appearance of centers of ossification during early childhood. Am. J. Dis. Child., *57:* 817–830.

Greulich, W. W. 1951 The growth and developmental status of Guamanian school children in 1947. Am. J. Phys. Anthrop., *9:* 55–70.

——— 1957 A comparison of the physical growth and development of American-born and native Japanese children. Ibid., *15:* 489–515.

Greulich, W. W., and S. I. Pyle 1950, 1958 Radiographic Atlas of Skeletal Development of the Hand and Wrist. Stanford University Press; Geoffrey Cumberlege, London; Oxford University Press.

Kelly, H. J. 1937 Anatomic age and its relation to stature. Univ. Iowa Stud. Child Welf., *12:* no. 5.

Keys, N., and W. W. Cadbury 1926 An age-height-weight study of Cantonese school boys. China Med. J., *40:* 14–24.

Lasker, G. W. 1946 Migration and physical differentiation: A comparison of immigrant with American-born Chinese. Am. J. Phys. Anthrop., *4:* 273–300.

Palmer, C. E., and A. Ciocco 1941 Growth Ann. Rev. Physiol., *3:* 79–106.

Pryor, J. W. 1905 Development of the bone of the hand as shown by the x-ray metho Bull. State Coll. Kentucky, Ser. 2. No. 5 Lexington, Ky.

Rotch, T. M. 1908 Chronologic and anatomi age in early life. J. Am. Med. Assoc., *51:* 1197-1205.

——— 1909 A study of the development o the bones in childhood by the roentgen metho with the view of establishing a developmenta index for the grading of and the protection o early life. Trans. Assoc. Am. Physicians, 24 603–624.

——— 1910 Roentgen ray methods applied t the grading of early life. Am. Phys. Edu Rev., *15:* 396–420.

Rotch, T. M., and H. W. Smith 1910 A stud of the development of the epiphyses of th hand and wrist for the purpose of classifyin the cadets at Annapolis. Trans. Assoc. Am Physicians, *25:* 200–211.

Shirokogoroff, S. M., and V. B. Appleton 192 Growth of Chinese. China Med. J., *38:* 400-413.

Stevenson, P. H. 1925 Collected anthropometri data on the Chinese. China Med. J., *39:* 855-898.

Stuart, H. C. 1946 Normal growth and deve- opment during adolescence. New Eng. J. Med *234:* 666–672, 693–700, 732–738.

Todd, T. W. 1937 Atlas of Skeletal Maturation (hand). The C. V. Mosby Company St. Louis.

Whyte, G. D. 1918 The height, weight an chest measurements of healthy Chinese. Chin Med. J., *32:* 210–216.

Rotation of the Otic Capsule in Bipedal Rats[1]

MELVIN L. MOSS
Department of Anatomy, College of Physicians and Surgeons,
Columbia University, New York

The processes of human evolution are notoriously resistant to controlled study. Nevertheless, it is possible to investigate ome aspects of these problems by appeal o an appropriate experimental model. The justification for such animal investigations is that ultimately all evolutionary processes express themselves in biologically meaningful terms. It is precisely at his biological level that our current methodologies permit us to gather valid data, which while perhaps not *directly* applicable to the human situation have at least he virtue of *indirectly* indicating general mechanisms.

The present paper deals with alterations in the skull concomitant with an alteration of habitual body posture. We have previously presented the theoretical basis for a unctional analysis of skull morphology Moss and Young, '60). In essence this nalytic method is an extension of the hypothesis of van der Klaauw ('52) that he skull is composed of a series of independent functional components, whose size, shape and spatial position have no *necessary* relationship to each other. This hypothesis has been repeatedly tested and xperimentally verified in this laboratory n a number of experimental and clinical ituations (Moss, '55a, '55b, '56a, '56b, '57a, '57b, '58a, '58b, '58c, '59, '60; Young, '60);

The organs of equilibration (the so-alled otolith organs) are such a pair of unctional cephalic components. They onsist of the sacculus, utriculus and three emicircular canal ampullae, all supplied by the vestibular division of the 8th cranial nerve. In all mammals, at least, these organs are enclosed within a bony otic capule. In a manner to be described later, hese organs are oriented in space in harmony with the usual carriage of the head.

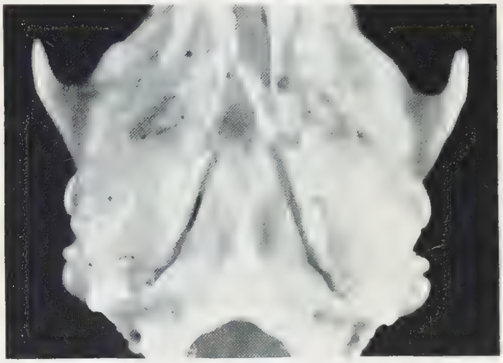


Fig. 1 Basal view of a boiled adult rat skull. Note the large fissures between the two globular otic capsules and the median skull base. These capsules may be easily removed from the skull by simple forceps pressure, there being no synostosis between them and their adjacent bones.

It was deemed of interest to determine (a) whether the spatial position of the otic capsules was necessarily related to adjacent cephalic structures, and (b) whether these organs are capable of spatial adjustment to experimentally produced changes in head carriage.

The rat furnishes an ideal test animal. Circumnatal amputation of the forelimbs has successfully produced what are in essence "bipedal rats," i.e., rats whose habitual mode of kinetic and static posture is permanently altered (Colton, '29; Pratt, '43; Goff and Landmesser, '57). In addition the otic capsule of the rat, at all ages, is totally free of (i.e., without synostosis to) its adjacent bones, being separated from them by a relatively thick layer of connective tissue (fig. 1).

---

[1] Aided, in part, by grants B-965(C5), and A-1930(C1) from the National Institutes of Health.

MATERIALS AND METHODS

Forty Long-Evans rats, three days of age, were divided equally into two experimental groups. Limb amputation was performed by tying 00 black suture silk about the free end of either the fore or hind limb pairs (20 rats each) as close to the body as possible. This was invariably followed by a dry gangrene, whose clinical course was the shriveling of the limb and its self-amputation in about 5 or 6 days. Sacrifice occurred on the 90 day of life. Previous work in this laboratory provided 20 control skeletons and skulls of 90-day rats.

Following sacrifice the heads were decapitated, boiled, bleached and dried. Each skull was x-rayed in a true lateral position with a Picker portable machine (10 ma, 50 KVP, 1 sec., Kodak no-screen film, cardboard cassette). From these films (fig. 2) tracings were made of: (1) the cerebral surface of the skull base, (2) the cribriform plate, (3) the outline of the otic capsule, (4) the ectocranial calvarial outline and (5) the nasal surface of the hard palate (fig. 3).

Two types of registration were employed using as a reference plane: (1) the cerebral surface of the skull base (fig. 4), or (2) the outline of the otic capsule (fig. 3). With the first registration method the following angles were determined: (a) cribriform angle, (b) palatal angle, (c) the angle of the foramen magnum and (d) the angle between the horizontal interparietal bone and the vertical occipital squama (the interparietal angle of Young, '60) (see: Moss, '58a). Using both methods of registration the general lateral contours of the skulls were traced on a master sheet. Using a mean calvarial contour, as determined by visual inspection, and the calculated mean values of the individu angles, modal tracings of the three grou were prepared. These in turn, were co pared by both registration methods.

Finally, both the pectoral and pelv girdles of all animals were recovered ar compared with controls.

RESULTS

Gross behavior. Amputation of eith pair of limbs did not result in any undu litter loss. The mothers accepted the o erated young, who nursed well, grew no mally and weaned at a normal age. Po ture was altered in all cases. The anima never became bipedal in the exact sens that is, they never walked erect on tw limbs at *all* times. The normal rat will fr quently stand erect on his hind limbs f brief intervals. However, in all cases th quadrupedal gait of the animals was se ously disturbed. Since these animals we operated on at an age before walking, p se, was an established activity, they d not have to *readjust* their mode of locom tion, but rather learn to move in the fa of certain produced anatomical handica

Limb removal. These animals who forelimbs were removed did not differ their locomotion or stance from the d scriptions of Pratt ('43). Their ability jump and to balance was unimpaired. Bo types of operated animals, however, d evidence a certain sort of anatomical r covery. That is, the embedded proxim portions of the limbs, which were una fected by the ligative procedures, c tinued to grow in length. As a result of the amputated animals eventually pr duced stumps of some size which th could and did use for a sort of quadrupec locomotion. Nevertheless, bipedal postu

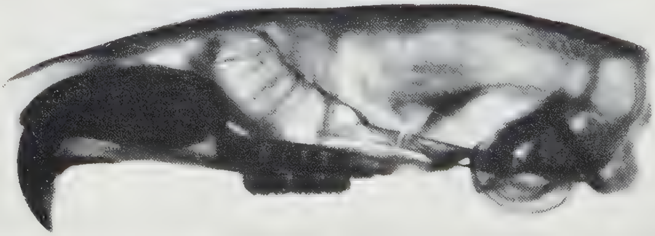


Fig. 2 Lateral x-ray of a prepared rat skull. Compare with figure 3.

and motion were more frequently observed than in controls.

In this upright posture one gained an impression which was difficult to objectify; that there was some sort of flexure or kyphosis of the skull relative to the now upright vertebral column.

No changes were noted in the form (i.e., size and shape) of either limb girdle.

Animals whose hind limbs were removed represented another picture. They most certainly did not walk about on their intact forelimbs. Neither did they seem able to use their hind limb stumps as satisfactory substitutes. Their gait was not uniform and seemed to consist in a series of short pushes or hops. The most noticeable thing about them was, among other things, apparent accentuation of their cervical vertebral curvature. The sum of these changes was an upward rotation of the skull.

X-ray studies. The reality of the subjectively noted alterations in head position were objectively established in the lateral x-ray films. The essence of these changes are shown in figures 3 and 4. With the mean tracings of each group registered on the virtually identical otic capsule outlines, both experimental groups demonstrated that the spatial position of the skull as a whole altered relative to a fixed otic capsule. It is important to note that the entire occipital-interparietal bone complex remained fixed relative to the otic capsule. In a word calvarial rotation occurred at some point anterior to the anterior lambdoidal suture. With a more erect posture, as in fore-limb removal, the skull as a whole rotated down and forward and became flatter. With the hindlimbs removed the reverse occurred; an upward and backward rotation and a more curved calvarial outline resulted. Figure 3 is a static presentation of the *final* position of the head in space, with the otic capsule and its enclosed semicircular canals held in a constant plane of space. The dynamic process by which this was attained is more clearly shown in figure 4. Here, with the otic capsules of each group registered on the reference plane of the cerebral surface of the skull base, we note that it was the otic capsules which rotated. We shall show below that this motion is not apparent but actual.

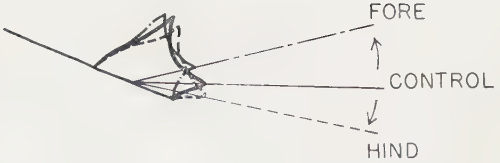


Fig. 4 Tracing of lateral skull x-rays oriented on the cerebral surface of the skull base. Note the change in position of the otic capsules in the experimental groups.

With the exception of the alteration of calvarial outline mentioned above, the measured cranial angles of all groups were normal. Their mean values did not differ significantly from those previously reported (Moss, '58a; Young, '60).

DISCUSSION

The removal of limb pairs is capable of altering the customary head position of the rat to such a degree that compensatory rotation of the otic capsule occurs. These data strongly suggest, if they do not definitely establish, that the otic capsule has no *necessary* spatial relation to adjacent cranial structures. The apparent exception of the occipito-interparietal complex will be discussed below.

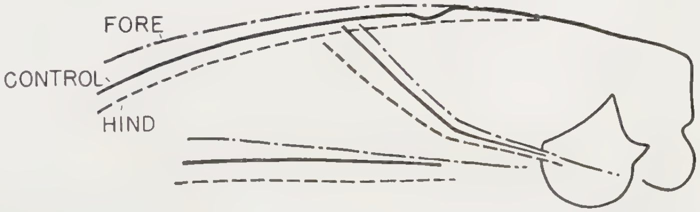


Fig. 3 Tracing of lateral skull x-rays oriented on the outlines of the otic capsules. The mean tracings of the control and of the two experimental groups are shown. Observe the constancy of the posterior cranial contour in the face of marked anterior motion in the experimental groups.

Physiology of balance. The significance of otic capsule rotation is made clear by a brief review of the physiology of balance. Posture is reflexly maintained on an afferent neural background from two main sources; the otic labyrinths and muscle proprioceptors. The labyrinth arises phylogenetically from the posterior portion of the primitive auditory sac, the anterior being modified into the auditory cochlea. This posterior portion is differentiated into the sacculus and the utricle which comprise the vestibule and the three semicircular canals. The vestibule represents the *otolith organ* found in all animals.

In mammals the hollow bony labyrinth contains within it a membranous labyrinth. Perilymphatic fluid separates the membranous from the bony layer, while endolymph fills the hollow membranous tube. In both the sacculus and utricle there are oval areas of thickened epithelium termed *maculae acusticae* which are special receptor organs. These maculae are composed of two types of modified epithelium, sustentacular cells and hair cells. The hair cells penetrate a tissue termed the *otolithic membrane* composed of a gelatinous substance in which a found numerous minute crystalline bodi of calcium carbonate, the *otoconia* or *ot* *liths*. The hair cells are intimately relate to fibers of the vestibular division of th 8th (auditory) cranial nerve.

There is general agreement that th otolith organs, and that the utricle in pa ticular, are chiefly concerned with *stat* position of the head and with linear a celeration while the semicircular cana are responsive to kinetic movements, chie ly rotations.

The function of the macula is shown i figure 5. Presumably the hair cells r ceive their minimal stimulation when th otolithic membrane is vertically above th macula. Any deviation from this postu produces a tension on the hair cells an triggers a firing of the associated neuron In normal head posture the mammalia utricle is horizontal with its otolithic mem brane above. Unlike stretch receptors muscles and tendons, this discharge show little adaptation, that is, the nerve fibe will continue to be stimulated as long the head is in this aberrant position.

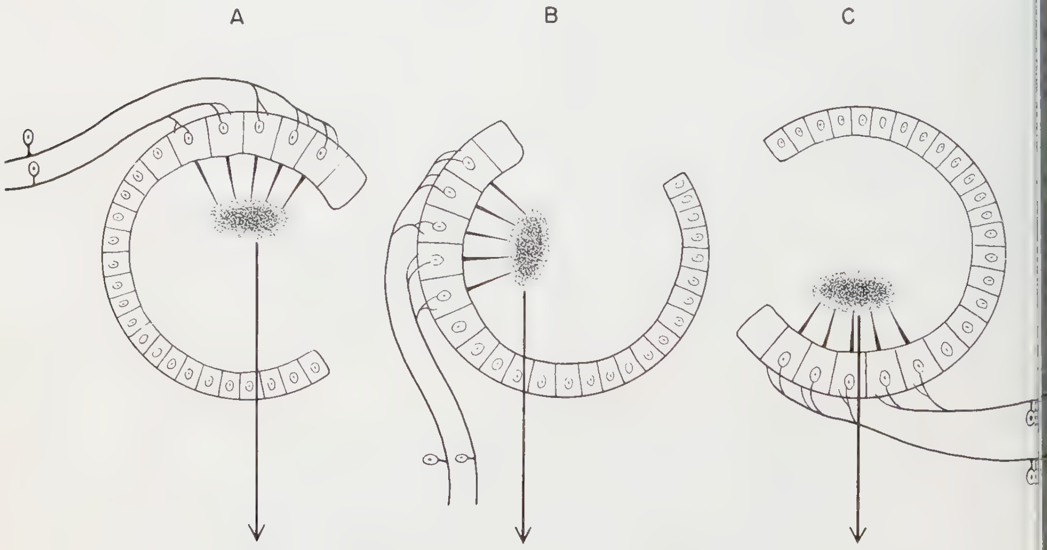


Fig. 5 Representation of macula function. The thickened epithelium of the macula is shown with hair cells connecting it to the otolithic membrane. The neurons represent the vestibular division of the 8th cranial nerve. Position (A) probably represents the position of maximal stimulation, while (C) is a position of minimal stimulation. The arrow represents the direction of gravity. After C. L. Evans ('49) Principles of Human Physiology, 10th ed. Lea and Febiger, Philadelphia.

Seemingly the operated animals are unble to completely compensate for the alration in habitual head position through hanges in the angulation of the cervical ertebrae. Since we do not understand he ultimate mechanisms involved, the est we can say at present is that the rat tic capsule is capable of rotation relave to the adjacent cranial structures in vhatever direction necessary to permit the tolith organs to regain a more nearly ormal orientation in space and so elimnate the constant afferent neural inflow.

Posterior cerebral fossa rotation. The onstancy of the spatial alteration of the ones forming the posterior cerebral fossa vith those of the otic capsule is easily xplained. We have previously demontrated that the cranial bones cannot proprly be considered as existing alone, but nust be reviewed as existing within a unctional matrix together with the dura nater with which they form a functional nit, a concept first proposed by Deggler '41) (see: Moss, '56a, '57a,b, '58a, '58b, 9). The rodent tentorium cerebelli, a rongly organized tract of dural fibers, rises bilaterally from the otic capsules nd sweeps upwards to gain endocranial alvarial attachment beneath the interarietal bone (see Moss, '58a for full deails). This upper attachment point is pparently where the currently observed alvarial outline changes occurred. Aparently none of the changes produced in nese experiments were capable of alterg the nature of the tentorium. Therere, the alteration of the post-tentorial ones became mechanically obligatory ith the changes in the basal attachment oints. The correctness of this view is upported by the observation that both atural and artificial deformation of hoologous calvarial areas in man produces echanically obligatory rotations of the ic capsule (Moss, '58c, '59).

Finally it must be remembered that in e rat there are definite alterations of anial form with age. The neonatal rat cial skull is strongly flexed ventrally lative to the neural skull (i.e., is klinhynchal). With age the entire facial ull rotates upwards until it comes to lie nterior to the neural skull and virtually in the same plane (Moss, '58a). Our present data make it appear that in rats with the forelimbs removed this process is accentuated while it is retarded in those with their hind limbs removed. Seemingly head carriage plays some role in the mutual adjustment of these two portions of the head.

Anthropological considerations. An entire school of mammalian craniology has recently arisen based upon the orientation of the otic capsules, with particular emphasis on the semicircular canals (see Delattre and Fenart, '58 for a comprehensive review and a complete literature citation up to that date).

In essence their methodology stipulates a constant plane of orientation of the horizontal semicircular canals. It is upon this plane that all skulls are registered for both comparative, phylogenetic and ontogenetic studies. One application of this method is shown in figure 6.

All of their publications have been theoretically analytic in nature, and indeed furnished the initial stimulus for the present investigation. We believe that our present data furnish the first experimental proof in support of their hypothesis, despite the fact that we did not study the semicircular canals, per se. It is important to note that the form of the labyrinth is homologous throughout the majority of the vertebrate series. This being so these rodent data appear to have some significance for man. We shall not delve in this discussion into the problems associated with the acquisition of upright posture in man. It seems sufficient to note that whatever genetic and/or environmental changes tended to bring about the necessary alterations of the pelvic girdle, vertebral column, lower limbs and occipito-atlanteal articulation, we need not postulate a similar mechanism for alteration in habitual head posture. Seemingly the otic capsules, which are relatively "free" of their surrounding bones during the first few postnatal years would be capable of rotating and reorienting themselves in a *mechanically obligatory* fashion when and if the animals habitually stood erect (see Delattre and Fenart, '59, for details

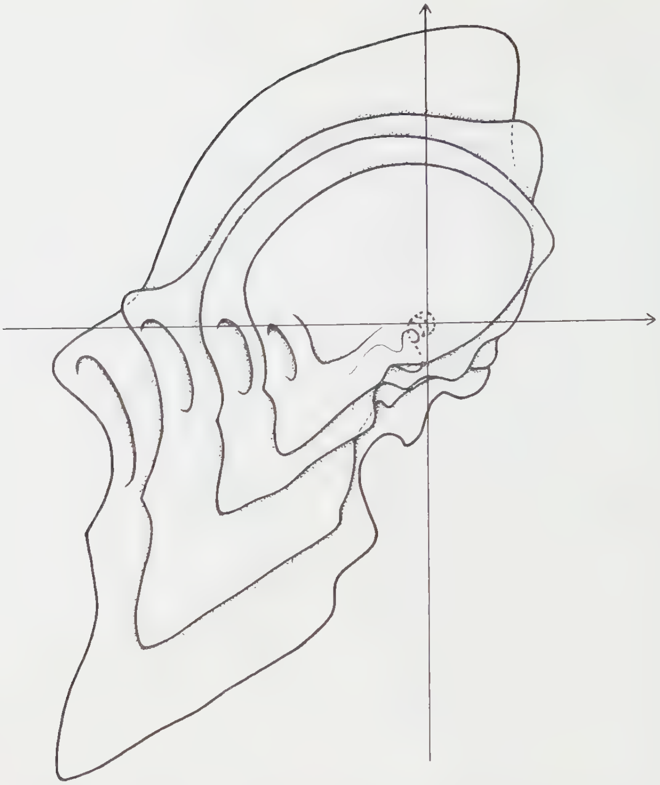


Fig. 6 An illustration of the use of the vestibular method of orientation in cranial studies. This figure illustrates the ontogenesis of the gorilla skull, registered on the axes of the horizontal and vertical semicircular canals. After Delattre and Fenart ('58).

of ontogenetic spatial alterations of the human petrous bone).

What other series of morphological alterations in the body might also passively (i.e., obligatorily) follow some primary mutational change or changes are unknown at present. This problem, however, is capable of appropriate experimental analysis. Along these lines we might just add that the lack of change in the limb girdles observed in the present experimental conditions demonstrates that continued activity of functionally associated muscles, rather than total limb function is necessary for the formation and retention of their adult osseous morphology.

SUMMARY

Ligative amputation of either fore- or hind-limb pairs were performed on neonatal rats. This was followed by changes in both habitual body and head positi
as well as by changes in cranial morph
ogy. The cranial changes consisted
(1) either accentuation (forelimb
moval) or retardation (hindlimb remov
of the usual extent of splanchnocran
rotation relative to the neural skull a
of (2) rotation of the otic capsules a
its functionally related posterior cereb
fossa. The physiologic basis for such
capsule movements were shown to be p
marily related to the need for reorien
tion of the utricular maculae. This de
onstration of the spatial independence
the otic capsules from adjacent cran
bones was held to support the hypothe
of Delattre and Fenart. The mech
ically obligatory nature of this rotation
a result of altered posture was discus
in the context of the acquisition of hum
upright posture.

LITERATURE CITED

Colton, S. H. 1929 How bipedal habit affects the bones of the hind legs of the albino rat. J. Exp. Zool., *53:* 1–11.

Deggler, C. 1941 Beitrag zur Kenntnis der Architektur des fetalen Schädels. Z. Anat. Entwicklungsgesch., *111:* 470–489.

Delattre, A., and R. Fenart 1958 La méthode vestibulaire. Z. Morph. Anthrop., *49:* 90–114.

——— 1959 Remarques sur la morphogenése des orifices de la face retro-tentoriale de l'os petroux humain. Bull. Soc. d'Anthrop., *10:* 326–356.

Goff, C. W., and W. Landmesser 1957 Bipedal rats and mice: laboratory animals for orthopedic research. J. Bone Jt. Surg., *39A:* 616–622.

Moss, M. L. 1955a Morphological changes in the growing rat skull following the administration of cortisone acetate. Proc. Soc. Exp. Biol. Med., *89:* 648–650.

——— 1955b Correlation of cranial base angulation with cephalic malformations and growth dysharmonies of dental interest. N. Y. State Dent. J., *21:* 452–454.

——— 1956a Malformations of the skull base associated with cleft palate deformity. Plast. Reconstr. Surg., *17:* 226–234.

——— 1956b Growth of certain human fetal cranial bones. Am. J. Anat., *98:* 191–204.

——— 1957a Experimental alteration of sutural area morphology. Anat. Rec., *127:* 569–590.

——— 1957b Premature synostosis of the frontal suture in the cleft palate skull. Plast. Reconstr. Surg., *20:* 199–205.

——— 1958a Rotations of the cranial components in the growing rat skull and their experimental alteration. Acta Anat., *32:* 65–86.

——— 1958b Fusion of the frontal suture in the rat. Am. J. Anat., *102:* 141–166.

——— 1958c The pathogenesis of artificial cranial deformation. Am. J. Phys. Anthrop., *16:* 269–286.

——— 1959 The pathogenesis of premature cranial synostosis in man. Acta Anat., *37:* 351–370.

——— 1960 Inhibition and stimulation of sutural fusion in the rat calvaria. Anat. Rec., *136:* 457–568.

Moss, M. L., and R. W. Young 1960 A functional approach to craniology. Am. J. Phys. Anthrop., *18:* 281–292.

Pratt, L. W. 1943 Behavior of bipedal rats. Bull. Johns Hopkins Hosp., *72:* 265–273.

van der Klaauw, C. J. Size and position of the functional components of the skull. Arch. Neerl. Zool., *8:* 1–559.

Young, R. W. 1960 The influence of cranial contents on postnatal growth of the skull in the rat. Am. J. Anat., *105:* 383–415.

he Liver of the Mountain Gorilla
(*Gorilla gorilla beringei*)

W. K. CHAGULA
Makerere College Medical School, Kampala, Uganda

Much that has been written on the go- lla liver has been on the liver of the low- nd gorilla, *Gorilla gorilla* (Elftman and tkinson, '50; Steiner, '54; Raven, '50). he only paper on the liver of the moun- in gorilla in the literature is that of All- rook, Galloway and Wilson ('59). This aper, however, is of no value since post ortem changes were well advanced by e time the liver and all the internal or- ans were removed for study. In that aper, in addition, the morphology of the ver was not described at all.

Regarding the microscopic appearance f the liver and other organs in apes, traus ('36) appropriately stated that "the nthropoid apes have not found their way nder the microscope, except on relatively re occasions." Three of these occasions ere relatively recently when Straus ('50) escribed the microscopic anatomy of the in of a young adult female lowland go- lla; when Rasmussen and Rasmussen (52) described the microscopic anatomy f the pituitary of a lowland gorilla, and hen Steiner ('54) described the histology f the liver and other organs in a 22-year- d lowland gorilla.

Studies on the microscopic anatomy of e mountain gorilla, on the other hand, re even more difficult to find in the liter- ure. In the paper by Allbrook et al. ('59), e authors stated that the post mortem anges in all the organs and tissues of e gorilla were "much too advanced for y worthwhile studies on the tissue cy- logy."

In view of the almost complete absence f both macroscopic and microscopic ana- mical studies of the mountain gorilla in e world literature, the present study is erefore regarded as a beginning in the llection of both morphological and histo- gical data on the mountain gorilla. The results of this study will be compared with those obtained from the study of the liver of the lowland gorilla in the literature.

A brief comparison of the morphology as well as the histology of the liver of the mountain gorilla with that of Man will also be made in this paper.

MATERIAL AND METHODS

The mountain gorilla whose liver is the subject of this paper, was found dead near Kisoro in Uganda on a Tuesday. The District Veterinary Officer had fortunately been following its movements for several days before it died. Therefore the post mortem changes in this gorilla, when it was found dead, were not as advanced as in the mountain gorilla described by Allbrook et al. ('59).

The Veterinary Officer was able to remove most of the internal organs (including the entire liver) which were immediately placed in a mixture of formalin and ethyl alcohol.

On the following Friday, specimens (for histological study) were removed from as many of the viscera as could be found. These specimens, including that from the liver, were transferred to a 10% formal saline solution.

The liver was first weighed and then its vertical and transverse measurements were obtained. Two line drawings of the liver, showing both anterior and visceral surfaces, were then made mainly to show the main fissures and lobules.

The morphology of the liver was described following the terminology used by Elftman and Atkinson ('50). For the histological study, following fixation in 10% formal saline for 48 hours, the liver specimens were dehydrated through a graded series of alcohols, cleared in xylol and finally embedded in paraffin-wax. Sections

10 μ thick were cut, deparaffinized in xylol and stained with hematoxylin and eosin. Some of the sections were stained by the Masson trichrome method and a few were stained by the Wilder's method for reticular fibers. Each of the sections was first compared, under the microscope, with a normal human liver which had been similarly stained. Lastly photomicrographs of the hematoxylin and eosin sections of the gorilla and human livers were obtained for comparison.

RESULTS

Gross anatomy and morphology

In general appearance the liver was roughly quadrilateral with a transverse measurement of 30.5 cm and a vertical height of 26.7 cm. It weighed 3900 gm following formalin-alcohol and formal saline fixation.

The falciform ligament was found on the inferior border of the liver immediately to the right of the second shallow notch. This ligament extended cranially, its two layers later separating to become the anterior layers of the coronary and left triangular ligaments respectively. There was a bare area, but its boundary was not well shown due probably to the careless removal of the liver from the peritoneal cavity. The liver was divided into right and left lobes by the falciform ligament, the right lobe being very slightly larger than the left.

The right lobe was further subdivided into a right central and a right lateral lobule, the latter having about one-third of the size of the former. The right lateral lobule was mostly situated on the visceral surface of the organ and the two lobules were separated by a deep fissure (fig. 1).

The right suprarenal gland was found lying on the postero-superior aspect of the right lateral lobule.

The left lobe was also subdivided by a deep fissure into a central and a left lateral lobule, the lateral lobule being from twice to thrice the size of the central lobule (fig. 1).

The fissure separating the two left lobules began at the inferior border of the liver and extended cranially both on the anterior and visceral surfaces of the gan. On the visceral surface, this fissu ran cranially and to the right and becam continuous with the fissure for the lig mentum teres (fig. 2). The inferior borc of the liver immediately to the left of t falciform ligament presented a seco notch which was 3.8 cm deep (fig. 1).

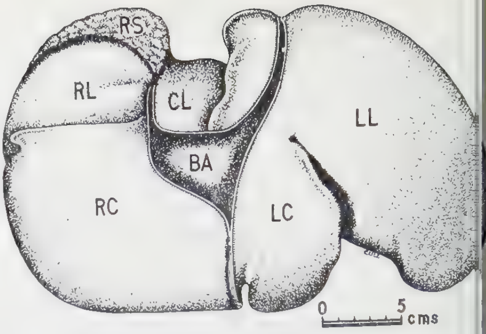


Fig. 1 Line drawing showing the anterior s face of the liver of the mountain gorilla. Key the figure: Right lateral lobule, RL; right c tral lobule, RC; right suprarenal gland, RS; c date lobe, CL; bare area, BA; left lateral lobu LL; left central lobule, LC.

The caudate lobe. This was well dev oped. It was 12.7 cm long, 3.8 cm wide its cranial end and 7.6 cm wide at its ca dal end.

The caudate lobe was continous, throu an isthmus, with the caudate proc which was situated cranial to the rig lateral lobule. The caudate process w roughly rhomboidal in shape and was co pletely separated from the right late lobule by a deep fissure (fig. 2).

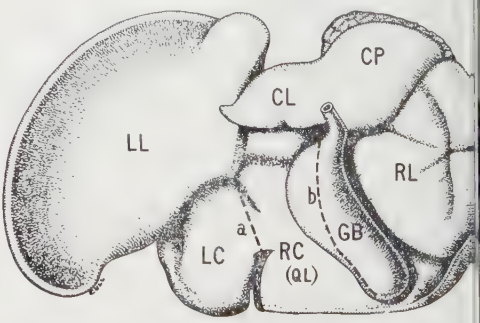


Fig. 2 Line drawing showing the visce surface of the liver of the mountain gorilla. to the figure: Caudate process, CP; gall blad GB; quadrate lobe (QL); LL, LC, RC, CL RL refer to the same lobules as in figure 1.

The quadrate lobe was not well marked. It was found to be roughly triangular with the apex of the triangle truncated at the porta hepatis.

The quadrate lobe was bounded by the gall bladder on the right and by the fissure for the ligamentum teres on the left. The latter fissure was in two parts with a bridge of liver tissue 5.1 cm long separating them (fig. 2, dotted line a).

About 3.8 cm from the porta hepatis and 10.2 cm from the inferior border of the liver, there was a shallow transverse fissure in the quadrate lobe. This fissure subdivided the quadrate lobe into two lobules.

The inferior vena cava was completely surrounded by liver tissue and was separated from the porta hepatis by the caudate process.

The gall bladder. This was 15.2 cm long and 5.1 cm wide. It was entirely on the visceral surface of the liver and so no part of it projected beyond the inferior margin of the liver. The gall bladder was lying towards the right central lobule so that its left attachment on its bed was hidden from view and is represented by the dotted line b in figure 2.

Microscopic anatomy

Both the human and mountain gorilla hematoxylin and eosin liver sections showed remarkable similarity regarding the size and arrangement of the cell cords, the sinusoidal and vascular patterns. This is well shown in figures 3 and 4 which are photomicrographs of the hematoxylin and eosin sections of a human and mountain gorilla liver respectively.

The mountain gorilla liver sections stained by the Wilder's reticulin stain were again indistinguishable from human liver sections similarly stained (fig. 5).

The Masson trichrome sections of the mountain gorilla liver showed that the disposition of both the intralobular and interlobular connective tissue as well as that of the connective tissue around the portal triads is similar to that in Man.

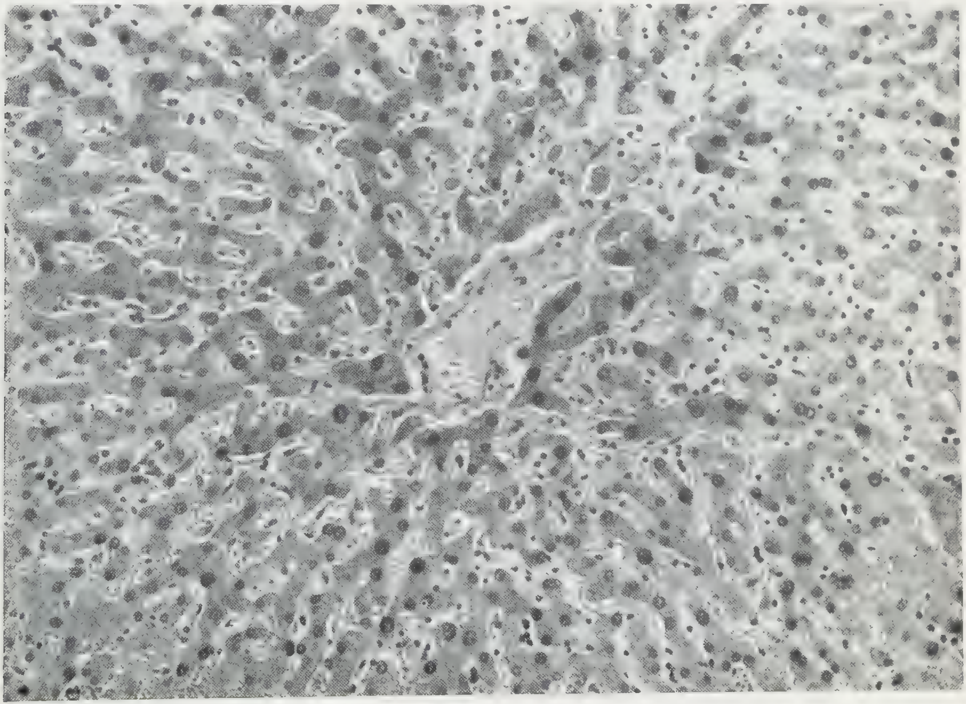


Fig. 3 Photomicrograph of a section of a human liver. Hematoxylin and eosin stains. × 176.

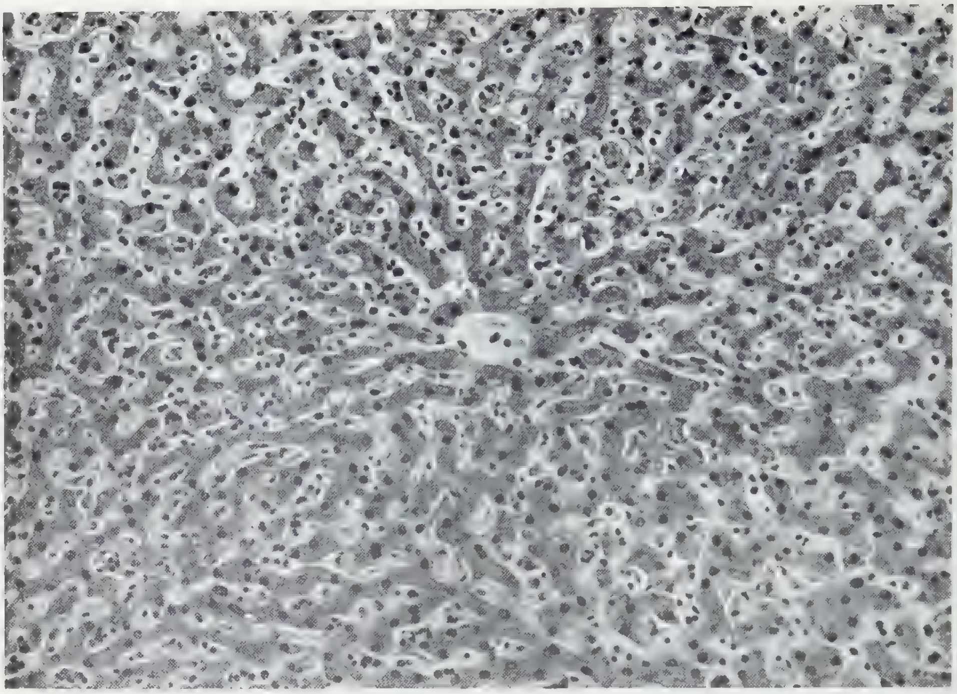


Fig. 4 Photomicrograph of a hematoxylin and eosin section of a mountain gorilla liver. × 176.

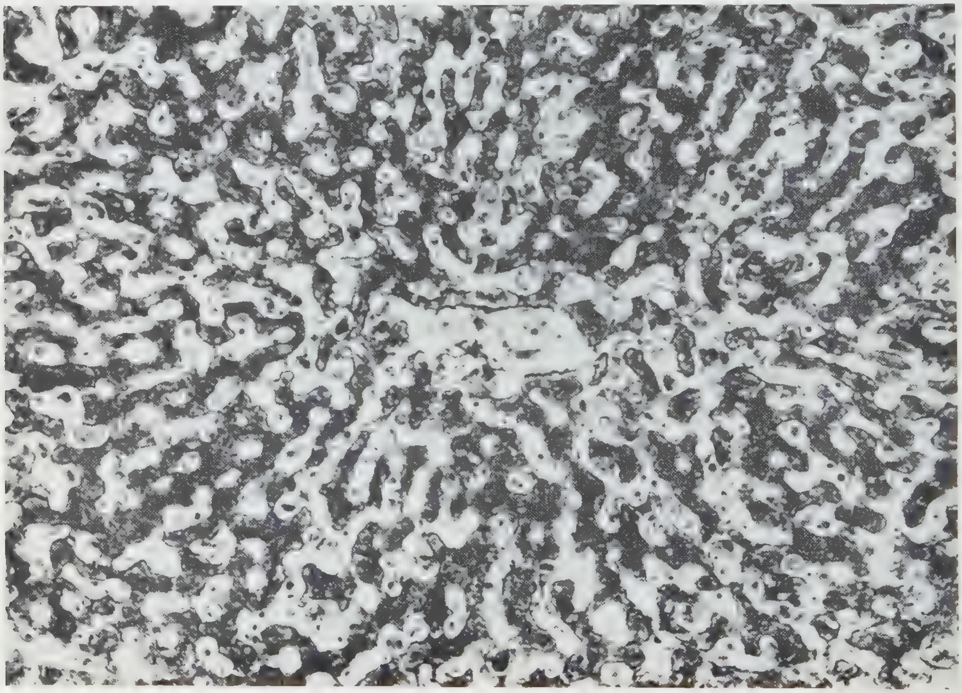


Fig. 5 Photomicrograph of a mountain gorilla liver section after staining with Wilder's reticulin stain. × 176.

DISCUSSION

Appearance and shape. In the mountain gorilla under discussion, the right lobe of the liver was hardly larger than the left lobe. This fact alone makes the appearance of the liver of the mountain gorilla very different from that of Man. Since it is unlikely that the general anatomy of the lowland gorilla can be significantly different from that of the mountain gorilla, the present author does not support Steiner ('54) in his statement that, except for its greater lobulation, the liver of the lowland gorilla grossly resembles a human liver. Further direct evidence in support of the author is provided by Elftman and Atkinson ('50). These authors also found that the liver of the lowland gorilla is more symmetrical than that of Man and that the right lobe is only slightly larger than the left.

It would therefore appear that Steiner's ('54) conclusions regarding the gorilla liver, differed from those of Elftman and Atkinson ('50) probably because they were based on a study of an atrophied liver. Unfortunately, however, in the lowland gorilla described by Steiner ('54), the effect of the atrophy of the liver on its appearance and general morphology cannot be assessed, since Elftman and Atkinson ('50) did not record the weight of the liver of their lowland gorilla.

Weight. The weight of the liver in this mountain gorilla (3900 gm) was well over twice the weight of an average-sized human liver (1500 gm). It is worth recording the fact that the liver constituted about 1/34 of the weight of the entire gorilla which was 134.1 kg (in Man the liver forms about 1/36 of the body weight). This weight is therefore probably the most accurate ever recorded for the weight of the liver of an adult mountain gorilla. In the adult mountain gorilla described by Allbrook et al. ('59), the extremely low weight of the liver (1818.2 gm) was most probably due to either post mortem change or atrophy or both. It is also relevant here to mention the figure of 2200 gm given by Steiner ('54) for the weight of the liver in the lowland gorilla he described. Steiner ('54) himself, however, believed this to be an atrophied liver, an opinion which is indirectly strengthened by the much greater weight recorded for the liver of the mountain gorilla by the present author.

General morphology of the gorilla liver

As regards the shape, the degree of lobation, the position of the falciform ligament and the presence of a bare area, the liver of the mountain gorilla under discussion is very similar to that of the lowland gorilla described by Elftman and Atkinson ('50).

The number of lobes in the liver of the lowland gorilla has been stated to vary from 4 (Koch, '37) to 6 (Elftman and Atkinson, '50; Raven, '50). In the mountain gorilla, if the quadrate and caudate lobes are included, the liver appears to have 6 lobes. If, however, the shallow fissure subdividing the quadrate lobe is considered, a total of 7 lobes can be seen.

Since in the paper by Steiner ('54) there was no figure or drawing showing the general morphology of the liver, it is difficult to understand what the author meant when he stated that "caudate and quadrate lobes were not developed" in the lowland gorilla he was describing. If Steiner ('54) meant that the lobes in question were present but not well developed, then the liver had at least 6 lobes. It would thus appear that in both the lowland and mountain gorillas, unless both the caudate and quadrate lobes are completely missing, the liver should have at least 6 lobes. In view of this ambiguity in the literature and the fact that very few gorilla livers have been critically studied in respect to the number of lobes, Steiner's ('54) conclusions that in the gorilla "it is apparent that the lobulation of the liver is more variable than in Man" should be accepted with caution.

The caudate lobe and caudate process. The comparison of the degree of development of the caudate lobe in the higher primates is almost impossible due to the inconsistency in the terminology used in the literature. Thus the "caudate lobe" of the old anatomists (Schäfer and Symington, 1898) is nowadays called the caudate process, while what is now generally called the caudate lobe (Johnston et al., '58; Hamilton et al., '56; Last, '54; Grant, '58;

Wood Jones, '50) was at one time generally known as the Spigelian lobe (Schäfer and Symington, 1898). This synonymity is very well brought out by Woerdeman ('50) who in his atlas refers to the caudate lobe (modern usage) as the "lobus caudatus (Spigeli)." In the absence of an accompanying diagram or figure showing the entire visceral surface of the liver, however, it is impossible to tell whether by "caudate lobe" an author is referring to the Spigelian lobe. Therefore most papers in the literature, which lack properly labeled illustrations of the visceral surface of the liver are useless when one is comparing the degree of development of the caudate lobe (modern usage) in the primates. Thus in view of these inconsistences in the literature, it will suffice only to record here that the caudate lobe (modern usage) was very well developed in this mountain gorilla.

The inferior vena cava. In this mountain gorilla this vessel had the same position as in the lowland gorilla described by Elftman and Atkinson ('50). In addition, the mountain gorilla displays the primitive condition as regards the position of the inferior vena cava, since this vessel is completely covered by hepatic tissue (Straus, '36).

The quadrate lobe. Though not well marked, in the mountain gorilla this lobe occupies the same position and has the same relations as in all primates where it exists (Thomson, 1899).

The gall bladder The position and relations of this organ in the mountain gorilla were the same as in the lowland gorilla described by Steiner ('54). The length of the gall bladder in this mountain gorilla (15.2 cm) on the other hand, lies between the lengths of the gall bladders in the lowland gorillas described by Koch ('37; 14 cm) and Steiner ('54; 17.5 cm). The greatest width of the gall bladder in this mountain gorilla (5.1 cm) was, however, only slightly greater than that in Steiner's lowland gorilla (4.5 cm). It is apparent then that the size of the gall bladder lies within the same range in both the mountain and lowland gorillas.

Microscopic anatomy

Since histologically the liver of th mountain gorilla is indistinguishable fro that of Man and since Steiner ('54) cam to the same conclusion in respect to th liver of the lowland gorilla, it can be re sonably concluded that there is no signif cant difference in the microscopic ana omy of the livers of both the lowland an mountain gorillas.

SUMMARY

1. The author has described both th macroscopic and microscopic anatomy o the liver of a mountain gorilla.

2. The gross morphology of the liver i the mountain gorilla has been found to b essentially the same as in the lowlan gorilla but very different from that i Man. Some aspects of the morphology a discussed.

3. The microscopic anatomy of th mountain gorilla liver has been found be indistinguishably the same as that the human liver.

ACKNOWLEDGMENTS

The author wishes to thank the follo ing people for their help: Professor Galloway for his encouragement and hel ful suggestions during the preparation o the paper, and Mr. P. G. Cull for the pre aration of the two line drawings and th photomicrographs.

LITERATURE CITED

Allbrook, D. B., A. Galloway and A. M. M. Wilso 1959 The study of Gorilla gorilla bering with a post mortem report by A. M. M. Wilso S. Afr. J. Sci., 55: 205–209.

Elftman, H., and W. B. Atkinson 1950 I The Anatomy of the Gorilla, W. K. Gregory, e Columbia Univ. Press, New York.

Grant, J. C. B. 1958 Method of Anatomy, 6 ed. Baillière, Tindall and Cox, Ltd., Londo

Johnston, T. B., D. V. Davies and F. Davie editors 1958 Gray's Anatomy. Longman Green and Co., London.

Koch, W. 1937 Cited by Steiner, Paul E., 195

Last, R. J. 1954 Anatomy Regional and A plied. J. and A. Churchill Ltd., London.

Rasmussen, A. T., and T. Rasmussen 195 The hypophysis cerebri of Bushman, the g rilla of Lincoln Park Zoo, Chicago. Anat. Re *113:* 325–347.

Raven, H. C. 1950 In: The Anatomy of t Gorilla, W. K. Gregory, ed. Columbia Uni Press, New York.

chäfer, E. A., and J. Symington 1898 In: Quain's Elements of Anatomy, vol. III, part IV. Longmans, Green and Co., London.

teiner, P. W. 1954 Anatomical observations in a *Gorilla gorilla*. Am. J. Phys. Anthrop., n.s. *12:* 145–165.

traus, W. L., Jr. 1936 The thoracic and abdominal viscera of primates with special references to the urang-utan. Proc. Am. Phil. Soc., *76:* 1–85.

——— 1950 The microscopic anatomy of the skin of the gorilla. In: The Anatomy of the Gorilla, W. K. Gregory, ed. Columbia Univ. Press, New York.

——— 1953 Cited by Steiner, Paul W., 1954.

Thomson, A. 1899 J. Anat. Physiol., London, *33:* 557.

Woerdeman, M. W. 1950 In: Atlas of Human Anatomy, vol. II. Butterworth and Co., Ltd., London.

Wood Jones, F. 1950 Buchanan's Manual of Anatomy, 8th ed. Baillière, Tindall and Cox, Ltd., London.

The Correlation Between External Cranial Volume and Brain Volume

JØRGEN BALSLEV JØRGENSEN, ERLING PARIDON AND FLEMMING QUAADE
Københavns Kommunehospital and Universitetets Antropologiske Laboratorium, Copenhagen, Denmark

A few years ago we were engaged in experiments with dry skulls. Our results (publ. in '56, together with an account of the measuring apparatus and method) proved to show (1) that there is a simple correlation between the cranial capacity and what we have termed the "external cranial volume"; and also (2) that this "external cranial volume" furnishes us with a more accurate estimate of cranial capacity than does the circumference of the skull.

However, seeing that cranial capacity cannot be said to equal the volume of the brain, we have now extended our investigation to comprising an autopsy material, in which we have compared the external cranial volume and the head circumference (both, this time, including the integuments) with the direct measurement of the brain volume.

Figure 1 illustrates the method: the head of the supine corpse is immersed into a container filled with water to the brim, until the surface reaches the horizontal glabella-inion plane. The displaced water is then collected and measured. Afterwards the brain is removed, and its volume is measured in the same manner, i.e. by immersion, etc.

The material consisted of 105 corpses, covering every age group. Nearly all the adults were men, as we wanted to avoid any inaccuracy caused by differences in hair volume. And as the brain is known to increase somewhat in weight — perhaps also in volume — after death (Appel and Appel, '42), each measurement was taken not earlier than 12 hours and not later than 24 hours post mortem.

Figures 2 and 3 show the relations between brain volume and external cranial volume, and between brain volume and head circumference. It will be seen that the external cranial volume is not directly proportional to the brain volume. This is different from the skull material, where we

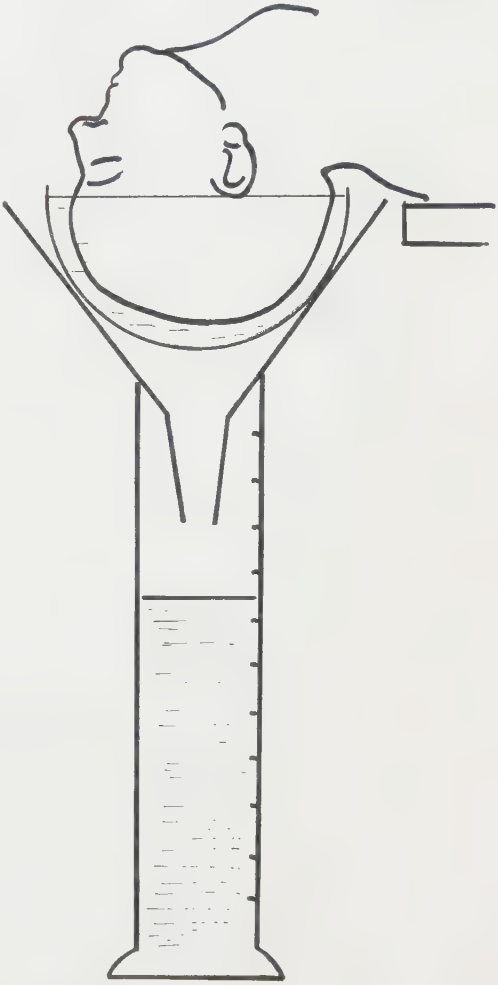


Fig. 1 Technique for measuring the external cranial volume.

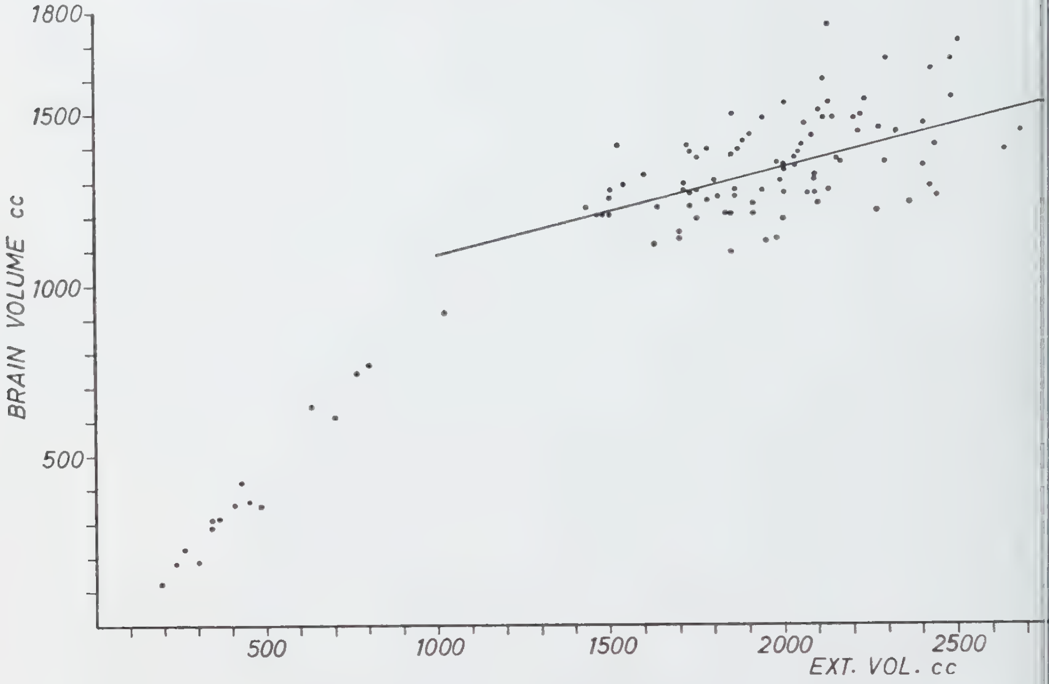


Fig. 2 Relation between brain volume and external cranial volume.

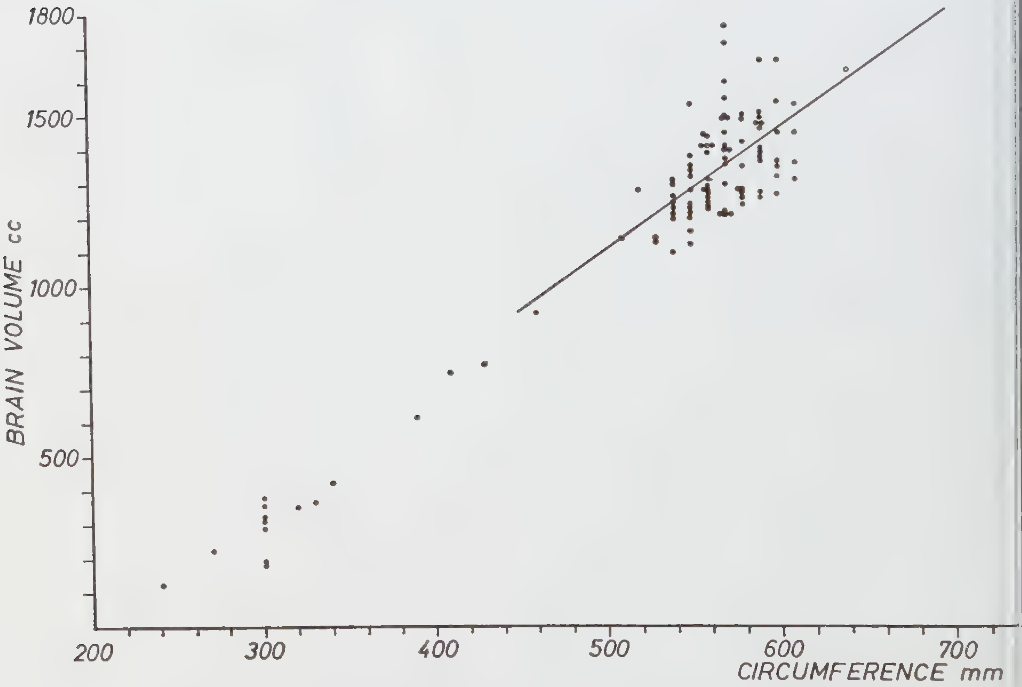


Fig. 3 Relation between brain volume and head circumference.

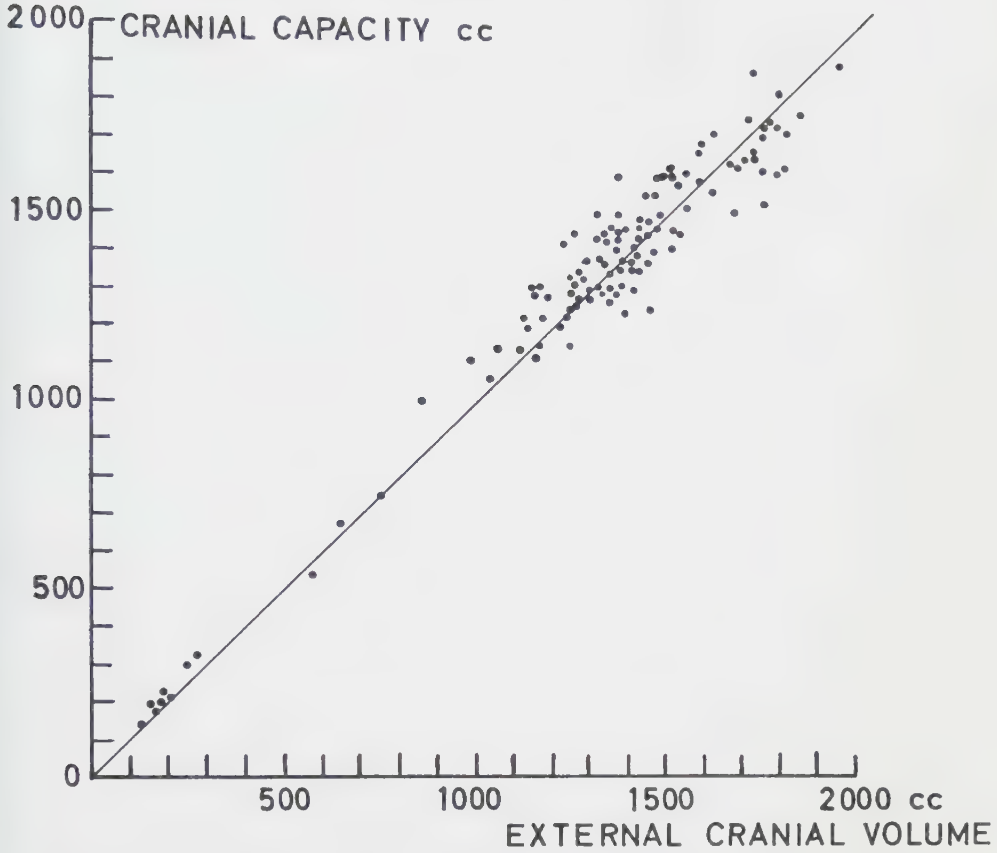


Fig. 4 Relation between external and internal cranial volumes in a series of 121 skulls.

found a simple one-to-one relationship between external cranial volume and cranial capacity (fig. 4). In other words: with increasing size of the head there is a relative increase of the intracranial space not occupied by the brain.

We reach the same result by comparing the two curves: circumference-brain volume (fig. 3) and circumference-cranial capacity (fig. 5).

If we omit the lowest 15 values and base a regression analysis on the remaining and more frequently occurring data, we get the following equation for figure 2:

$$y = 0.25x + 840 \quad (s_E = 120)$$

and for figure 3:

$$y = 36x - 700 \quad (s_E = 115)$$

where x represents cc in the first equation, and cm in the second.

To all intents and purposes the two s_E values are identical, which seems to prove that we can estimate the volume of the brain with the same amount of accuracy whether we found our calculation on the circumference or on the external cranial volume.

Still there is one important reason for preferring the latter course. We can hardly expect to measure the head circumference with a smaller margin of error than 1 cm, corresponding to an error of 35 cc in the computation of the brain volume; on the other hand repeated measurements of the external cranial volume have proved to give a margin of error of 50 cc, reducing the corresponding error in the computation of the brain volume to no more than 15 cc.

The water displacement method has later proved useful for measuring the external cranial volume of normal children and of macro- and microcephalic children (J. B. Jørgensen, E. Paridon, and F. Quaade, '59).

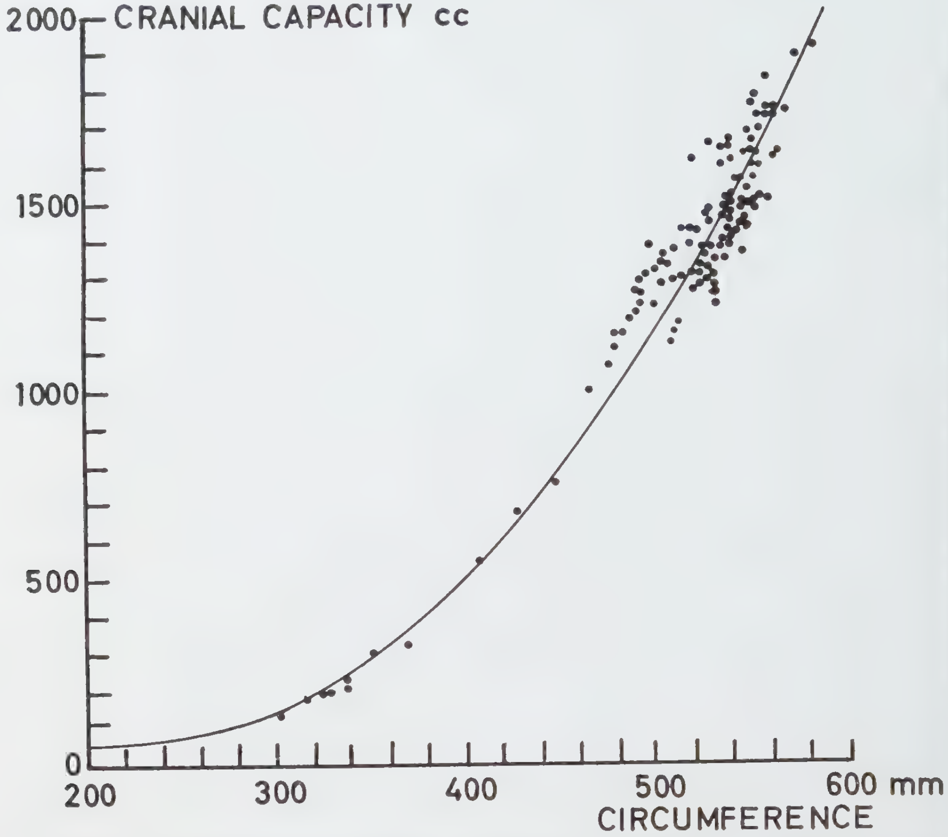


Fig. 5 Relation between cranial circumference and internal volume in a series of 121 skulls.

CONCLUSIONS

The volume of the human brain can be computed either by measuring the external cranial volume or by measuring the circumference of the head, but the former course of action ensures a more accurate result than the latter. With increasing head volume the brain occupies a relatively smaller part of the intracranial space.

The following method was used in the regression analyses:

The equation for the straight line:

$$y = \bar{y} + b(x - \bar{x})$$

where

$$\bar{y} = \frac{\Sigma y}{n}$$

and

$$\bar{x} = \frac{\Sigma x}{n}$$

$$b = \frac{SP_{xy}}{SK_x}$$

$$SP_{xy} = \Sigma xy - \frac{\Sigma x\, \Sigma y}{n}$$

$$SK_x = \Sigma x^2 - \frac{(\Sigma x)^2}{n}$$

$$SK_y = \Sigma y^2 - \frac{(\Sigma_y)^2}{n}$$

The variance for y around this line w computed from the formula:

$$S_E^2 = \frac{1}{n-2}(SK_y - \frac{SP_{xy}^2}{SK_x})$$

LITERATURE CITED

Appel, F. W., and E. M. Appel 1942 Intr cranial variation in the weight of the hum brain I-II. Human Biology, *14:* 48–235.

Jørgensen, J. B., and F. Quaade 1956 Extern cranial volume as an estimate of cranial capa ity. Am. J. Phys. Anthrop., *14:* 661.

Jørgensen, J. B., E. Paridon and F. Quaade 19 The external cranial volume of normal childre Acta Paediat., *48:* 371–378.

——— 1959 The external cranial volume macro- and microcephalic children. Ibid., 469–476.

Some Aspects of Skeletal Development Through Adolescence

I. VARIATIONS IN THE RATE AND PATTERN OF SKELETAL MATURATION AT PUBERTY

DAVID HEWITT[1] AND ROY M. ACHESON[2]
Department of Social Medicine, University of Oxford, England, and Department of Social and Preventive Medicine, Guy's Hospital Medical School, London, England

There is little in the extensive literature on skeletal maturation to suggest that this process might be subject to an adolescent spurt, presumably because the usual method of assessing skeletal maturity precludes the recognition of any variation in the maturation rate of children as a whole. The essence of this, the skeletal age method (Todd, '37; Greulich and Pyle, '50, '59; Pyle and Hoerr, '55), is that a large number of radiographs of a body area (e.g., the hand or knee) of children of a particular age are ranked in order of skeletal maturity and the median is selected as a standard for that age. An individual radiograph is then said to exhibit the "skeletal age" corresponding to the standard which it most closely resembles. Consequently the average distance curve (Tanner, '55) for "skeletal age" is *by definition* a straight line at 45 degrees through the origin (zero skeletal months at birth), while the corresponding increment or velocity curve must be a horizontal straight line, and the average acceleration of any healthy group cannot deviate from zero except by chance (until the adult limit of maturity is reached when there is bound to be deceleration). It is the purpose of this paper to consider changes in the rate of skeletal maturation, both by arguing from the Atlases which form the basic standard of the skeletal age method, and by using a different technique for assessing skeletal maturity.

MATERIAL AND METHOD

All the data are drawn from the Brush Foundation Growth Study at Western Reserve University Medical School. The subjects were healthy children living in prosperous homes in the city of Cleveland, Ohio, who were born at various dates between 1931 and 1942. Some arguments in the present paper are deduced from Brush Foundation material already published by other authors (Todd, '37; Simmons, '44; Greulich and Pyle, '50; Pyle and Hoerr, '55) and some from a further analysis of data which we ourselves have carried out. For this latter purpose a deliberate selection was made of 400 of the most complete case histories (225 boys and 175 girls), but there is no reason to believe that the resulting sample of children differed in any systematic way from the Brush "Regular Series" (Simmons, '44) to which most of them belonged.

A new set of assessments of skeletal maturity were made from postero-anterior radiographs of the left hip joint and innominate bone by one of us (R.M.A.) using the Oxford method, full details of which have been set out elsewhere (Acheson, '57). Like other inspectional methods for estimating skeletal maturity it is based on the fact that ossification of the cartilaginous skeleton is an irreversible process. As new bone replaces cartilage it takes up characteristic shapes, known as maturity indicators, each of which can be recognized on radiographs taken under standard conditions. Each such indicator belongs to a series within which the sequence is the same for all children but indicators belonging to *different* series do not necessarily appear in a standard sequence, as will be shown below. The indicators belonging to a given series can therefore be numbered in order, and the presence of (say) indicator 4 of the series appearing at the head of the femur means that indicator 3 must must have been present previously while indicator 5 has yet to appear. It is thus possible to say that a child who exhibits indicator 4 of the head-of-femur series has attained a score of 4 points for that series, and to derive a maturity score for any area of the body by adding up the scores for a number of indicator series. In the hip and pelvis region 9 such series are distinguished comprising 45 indicators in all (when one side of the body only is assessed).

---

[1] 8, Keble Road, Oxford.

[2] Department of Social and Preventive Medicine, Guy's Hospital, London, S.E.1.

RESULTS

1. *Evidence of a pre-pubertal maturation spurt from the skeletal age atlases for hand and knee*

"Skeletal age" assessments might provide the basis for demonstrating an adolescent spurt because, assuming that this occurred earlier in girls than in boys, we should find some age at which the age-group mean for girls accelerated away from the boys' mean, and a later age at which the boys' mean accelerated to catch up again.

This was, in effect, done by Todd himself when he drew up a list of "sex-equivalencies" between the hand film standards of his 1937 Atlas, some of which are quoted in table 1. The right hand column of this table gives figures for the implied lead of the average girl over the average boy; this lead is seen to vary in a way which strongly suggests that there is a pubertal spurt i maturation of the hand, and this seems start at a younger age than the spurt f most body measurements. A similar seri of comparisons between the sexes can b obtained from the Knee Atlas (Pyle an Hoerr, '55) in which each plate serves a a dual standard for boys and for girls. Fo example, the plate chosen as typical of 9-year-old boy is also said to be typical o a 7-year-old girl, implying a girls' lead this stage of two "skeletal years," or to p it another way the time in months take from conception to the attainment of th stage by the average boy is 117/93 or 1.2 times as long as for the average girl. subsequent plate serves both for boys 12 and girls of 9, implying that the inte vening stages of development occupy bo for 36/24 = 1.5 times as long as girl later, however, the boys require only tw years 10 months to traverse the stages b tween the girls' standards for 9 and years, that is, only 0.94 of the time take by girls. Thus, both in the hand and th knee, sex comparisons expressed in term of "skeletal age" equivalencies show th features expected in the case of a pubert spurt: a relative acceleration in girls fo lowed by a relative acceleration in boy There is an important difference betwe the two areas, however, namely that in th knee the girls show a much larger pre pubertal lead, so that the "extra" le which they attain by virtue of their earli puberty constitutes a smaller part of the total lead at that time.

Although these comparisons between th sexes are somewhat unsatisfactory becau they are not derived from any actual a sessments of boys' and girls' films again

TABLE 1

Some male and female standards from Todd's ('37) Atlas which show an equivalent stage of skeletal maturity

Boys' standard			Girls' standard			Implied lead of girls over boys (months)
No. of standard	Skeletal age		No. of standard	Skeletal age		
	Yrs.	Mths.		Yrs.	Mths.	
19	8	3	18	7	9	6
22	9	9	20	8	9	12
24	10	9	21	9	3	18
27	12	3	23	10	3	24
29	13	3	25	11	3	24
31	14	3	28	12	9	18

a common series of standards, they are quite satisfactory for comparing groups within either sex which reach puberty at different ages. Material for such a comparison has more than once been published. Greulich and Pyle ('50), for instance, gave a graph of age-group means of "skeletal age" of the hand for three groups of girls whose menarche occurred (a) before the 12th birthday, (b) between the 12th and 13th birthdays, and (c) later than the 13th birthday. The feature of this graph selected for comment both in the original publication and when reproduced by Tanner ('55) was that as far back as age 7 the three menarcheal groups had distinctly separated means for "skeletal age." Close inspection, however, shows that the differences between these groups were far from constant, and in fact varied in a manner which could reasonably be explained by assuming the occurrence of a considerable adolescent spurt in skeletal maturation. Groups (a) and (c), which were separated by only about 14 or 15 "skeletal months" at ages 7 to 12, diverged abruptly between the ages of 12 and 13 and at age 14 passed a maximum difference of nearly 24 "skeletal months" before converging again. Simmons and Greulich ('43) laid out data on three similarly defined groups of girls in the form of increment curves (their fig. 10). Two of these groups showed the peak increment typical of measurements subject to an adolescent spurt. The authors suggested that the declining phase of the increment curve following this peak was largely an artefact, and failed to comment at all on the preceding rise.

Thus, in spite of the use of a scale of measurement which assumes skeletal maturation to proceed linearly with age, phenomena are found which can only be explained by postulating the occurrence of an important spurt, characteristically occurring earlier in girls than in boys, and especially so in girls who reach sexual maturity early. If, however, the process of skeletal maturation does accelerate at puberty, no analysis based on the skeletal age system of assessment can show the full extent of the acceleration, because the condition that average skeletal age should be rectilinear with chronological age throughout the developmental period entails that the skeletal age scale itself must be "stretched" during the years when maturation is proceeding more rapidly. That is, successive standard films for adolescent children must show a greater difference or, in terms of a true maturity scale, be placed further apart than successive standards for younger children although both are nominally separated by the same "skeletal months" interval.

A realistic estimate of the magnitude of the acceleration requires a maturity scale based on units more natural than "skeletal months." The only such scale yet published which covers the adolescent years is that constructed by the Oxford Method and applied to the head of femur and os innominatum (Acheson, '57)[3]; it is this which forms the basis of the analyses presented in the following sections.

2. *Evidence of a pre-pubertal spurt using the Oxford Method for hip joint and innominate bone combined*

Age-group means for total hip maturity score assessed by the Oxford Method were given in the original publication (Acheson, '57). From the same data the increments for each child for each year have now been calculated and averaged and the resulting increment or velocity curves are shown by sex in figure 1. These curves are clearly of the same general form as those familiar for most physical dimensions: there is an infantile phase of rapid development, a period of slowed development in mid-childhood (more protracted for boys than for girls), and a pubertal acceleration leading up to a prominent peak. Although the peak increments for hip maturation appear strikingly high in relation to the increments of the earliest years, they are not much higher relative to the pre-pubertal minima than those in the increment curves for weight. The maturation peaks occur considerably later than the maxima found for most types of growth, including increase in hip width (Shuttleworth, '37). The implication is not, however, that the pubertal

---

[3] A scale of the same type has been prepared for the assessment of the short bones of the hand (Moss and Noback, '58).

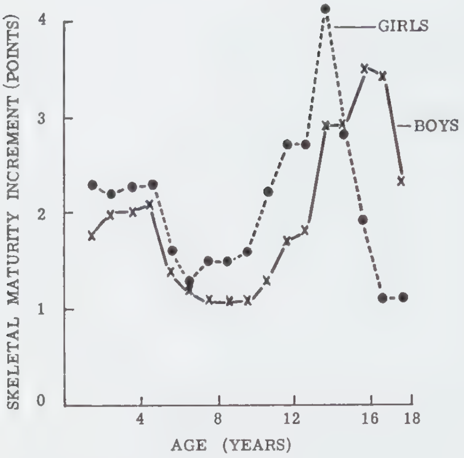


Fig. 1 Mean annual increments in skeletal maturity for the hip region from the second to the 18th year of life.

*ac*celeration occurs late, but rather that the post-pubertal *de*celeration is late. That is, the increased rate of development is sustained much longer than is usual in growth velocity curves; it will be noted that the acceleration originates at least 4 years before the peak in each sex.

Besides changing the shape of the age-trend for skeletal maturity from the linear form assumed in the "skeletal age" method, the Oxford Method also gives a different age-trend to the scatter of maturity assessments. This latter change is also just what would be expected from the substitution of a natural for a "stretched" scale. Thus, in the hand data presented by Greulich and Pyle ('50, p. 33) the girls' age-group with the greatest scatter is that at age 11 years, when the standard deviation is only 24% greater than at age 7. Over the same interval the standard deviation of the Oxford points score increased by 50%, and at 13 it was more than double the 7-year-old value (Acheson, '57); some of this contrast may, of course, be due to genuine difference between the hand and hip.

3. *Selective acceleration of ossification within the hip region*

The acceleration of skeletal growth which occurs at puberty does not involve chondroplasia in all growth cartilage simultaneously or to the same extent (Shuttleworth, '38), nor does it affect the two sex in the same way. On the contrary, it the differential accelerations of this peri which largely determine the evolution the characteristic male and female adu skeletons from the relatively undifferen iated forms of young boys and girls. O might therefore expect to find with t advent of puberty evidence of great changes in the rate of osteogenesis in som areas than in others, and this indeed prov to be the case.

The 9 series of indicators used in t Oxford Method for the hip and pelvis ma be divided into a femoral group (head femur, greater trochanter, lesser trocha ter) with a maximum or mature score 20 points, and a pelvic group all composi parts of the innominate bone (iliu ischium, junction of ischial and pub rami, pubis, triradiate cartilage) with mature score of 25 points. Age-grou means have been calculated for these tw groups of indicators, and the relative pro ress of the two sexes exhibited graphical (see figs. 2(a) and 2(b)).

Figure 2(a) shows that the femur co forms to what is regarded as the norm pattern of events in skeletal maturatio From an age not later than 18 mont (when the head of the femur in the ave age girl first becomes visible) girls a clearly ahead of boys. Moreover, up to t stage at which girls have on average on one more point to gain, the crosses are a very close to one straight line. The pos tion can be fairly summarized by sayi that throughout their development gi have a maturation rate in the proximal e of the femur about 25% faster than that boys. More detailed analysis (see section suggests that there is some acceleration maturation in the femur during pubert which would be expected to cause a te porary exaggeration of the girls' lead, bu as figure 2(a) shows, this must be small relation to the total difference between t sexes. In fact the sex-comparisons o tained from figure 2(a) are not unlike tho for the knee previously inferred from t sex-equivalents in the Pyle-Hoerr Atl ('55). This is interesting because in eac case the growing end of a long bone whic contributes significantly to stature is i volved.

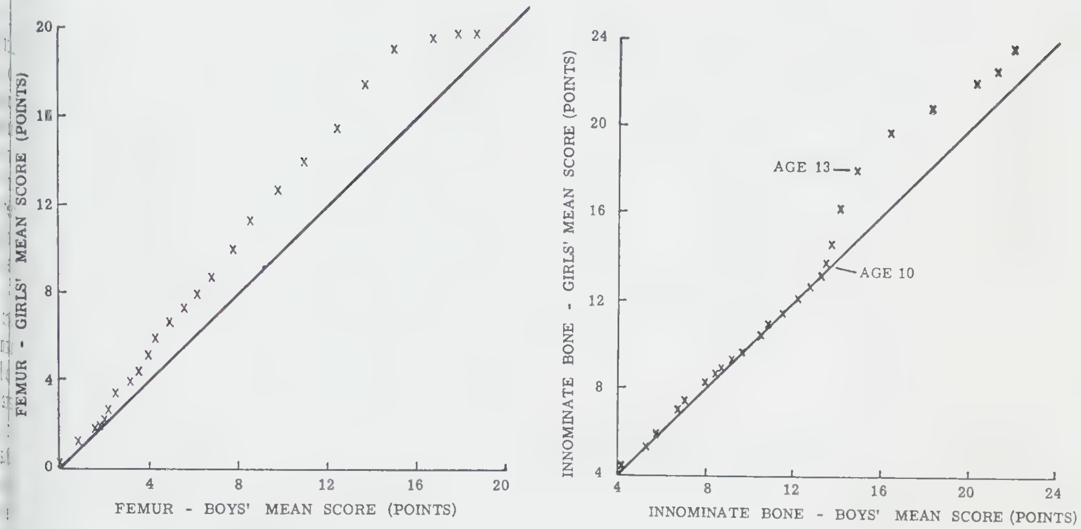


Figure 2a

Figure 2b

Fig. 2 Annual mean skeletal maturity scores for boys plotted against those for girls at ages three months to 18 years: (a) the femur, and (b) the innominate bone. The 25 crosses on each of these graphs represent ages from three months to one year at three-monthly intervals, to 5 years at 6-monthly intervals and then by annual intervals to 18 years.

The pattern of events in the pelvic group of indicator series is totally different (see fig. 2(b)). Over the first decade of life the sexes have indistinguishable mean rates of development and at age 10 boys and girls both average between 13 and 14 points. Between ages 10 and 13 years, however, girls are estimated to achieve an average maturity increment for the os innominatum which is 3½ to 4 times as great as boys, while after their 13th birthday the boys show a relative acceleration and the crosses in the figure begin to converge towards the line of equal development. Clearly, maturation of the pelvis is much more responsive to the steriod hormones of puberty (see Hewitt and Acheson, '61) than is that of the femur.

It is plain from figure 2(b) that maturity acceleration occurs at an earlier average age in girls than boys (a fact which is known to be also true of height acceleration). Owing to the more rapid femoral maturation of girls, however, these pubertal accelerations in the innominate bone occur at a closely comparable stage of femoral development in each sex and probably at a similar stage in the development of the long bones generally. Therefore on reaching puberty, boys and girls still have about the same period of longitudinal growth before them. The significance of this comparison between the sexes will be discussed further in section 6 below, where it will be contrasted with the difference between fast and slow maturers within a single sex.

4. *A sex-difference in the pattern of skeletal maturation at puberty*

Since the relative maturation rates of boys and girls are different for the femur and the innominate bone it follows that some maturity indicators at least must tend to appear in a different order in the two sexes. This was confirmed by ranking all children with a newly acquired score of 14 points for the innominate bone (i.e., those who had a score for the innominate bone of 13 or less on their previous birthday) by the contemporary score for their femur (see table 2). At this fixed stage of development of the pelvis, which was usually achieved by completion of the ossification of the primary centers of the innominate bone the percentage of girls with a

TABLE 2

Boys and girls of the Brush Foundation Series who had just attained a maturity score of 14 for the innominate bone classified according to maturity points score for the femur

	Femur maturity score (points)		Total
	9 or less	10 or more	
Boys	85 (65.4%)	45 (34.6%)	130
Girls	33 (30.0%)	77 (70.0%)	110
Total	118 (49.2%)	122 (50.8%)	240

$\chi^2_{(1)} = 28.441$; $P < 10^{-7}$.

femur score of 10 points or more (70.0%) was twice as great as the corresponding percentage of boys (34.6%), a difference which is far too great to attribute to chance (P < 0.000,000,1). An identical pattern has been observed by the present authors in data from another growth study which is not currently available for publication.

One consequence of this finding is that it would be impossible to establish sex-equivalencies between any radiographs intended to serve as Atlas standards for the hip and pelvis region as a whole. This is not in itself of much practical importance, but it would be much more serious if — as will be suggested below (section 6) — there should be constitutional variation in the pattern of maturation *within* as well as between the sexes, because the Atlas method of assessment relies for its validity on the assumption that, at least within sexes, there is only one "normal" sequence of ossification.

5. *Relation between accelerated skeletal maturation and puberty in girls*

We have shown above (section 2) that the total maturity score for the region for girls as a whole accelerates, relative to that of boys as a whole, at about 11 to 12 years of age, and have interpreted this as evidence of a genuine spurt in the rate of skeletal maturation. If such an interpretation is correct, it should follow that before the age of 11 the hip maturity scores of girls who reach menarche early should already be accelerating away from the scores of those who reach it late.

This hypothesis was first tested
means of a correlation analysis which
summarized in figure 3 where the correl
tion between total hip maturity score ar
age at menarche is plotted against chron
logical age. The negative correlation coe
ficients signify that those with *higher* m
turity scores achieve menarche at
younger age. The correlations increa
from values smaller than − 0.2 at ag
under age 9 to a maximum of nearly − 0
between the ages of 12 and 13, and the
they decline much more gradually tha
they increased. Something like the appea
ance of figure 3 might have been produce
artificially if the intrinsic reliability of tl
actual assessments had been much low
at the earlier ages. Such evidence as
available from duplicate readings on th
and other data, however, suggests that ar
improvement in the reliability of the h
score between the ages of 9 and 12 cou
have made only a trivial contribution
the very steep rise in the correlation coe
ficient. Furthermore, Nicolson and Hanl
('53) obtained a similar correlation pa
tern between age at menarche and tl
skeletal age of the hand.

The contributions made by the femor
and pelvic maturity indicators to this i
tensified relationship are very unequal,
fact which can be demonstrated by an ana
ysis of the maturity increments achieve
by 52 girls of known age at menarche f

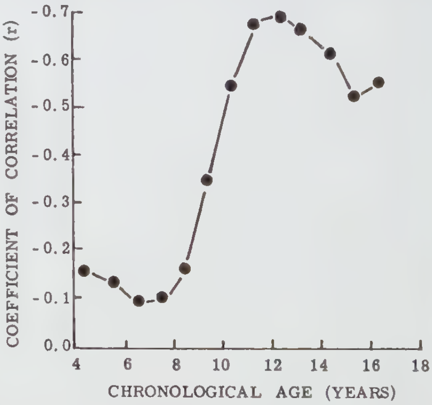


Fig. 3 Age trend of correlation between tl
total hip maturity score and age at menarch
Each of the points plotted is the mean of tw
correlation coefficients, one estimated at precedir
and one at the following birthday. The numb
of girls in the sample varies between 27 and 97.

whom hip films were available both at 9 and 12 years of age. Within this group the 24 girls who reached their menarche before he age of 12½ years gained on average 2.03 more points between ages 9 and 12 than did the remaining 28 girls. This difference in the total hip increment was made up of an insignificant ($P > 0.30$) contribution of 0.25 points from the femur series and a much more important ($P < 0.001$) contribution of 1.78 points from he innominate bone.

During the pre-pubertal years there was much sharper contrast between age-at-menarche groups on the basis of femoral than of pelvic scores, but as in the comparison between the sexes, the differential rate of maturation in the innominate bone between those with early and those with late menarche first manifested itself at puberty. This is shown in figure 4 where the mean differences for femoral and pelvic scores between girls reaching menarche before 12½ years and the rest are shown for each age group from 5 to 16 years. At ages 6, 7 and 8 the girls who were to reach menarche relatively early actually had a slightly lower mean score for the innominate bone, and at age 9 the two age-at-menarche groups had identical mean scores. By age 10, however, the "early" girls had established a technically significant lead, and by 12 there was more than a whole standard deviation between the means of the two groups, a degree of differentiation which persisted for at least 4 years. The "early" girls lead in respect of femur score shows comparatively little variation. At the younger ages shortage of numbers makes the estimation of this lead very unreliable, but it was found to be significantly greater than zero at ages 3 and 4 years neither of which are shown in figure 4, — as well as at all but the last of the ages which are shown in the figure.

6. *Differences between early- and late-maturing girls in the pattern of skeletal development*

We have compared the skeletal maturation of boys and girls as a whole as well as that of early- and late-maturing girls, and have established that in each case the group which matures earlier sexually has, during the pre-pubertal years, a substantial lead in the maturation of the femur but *no* lead in the pelvis. Therefore the sex difference in ossification sequence shown above (table 2) must also have some parallel in the within-sex comparison. In making the between-sex analysis (table 2) scores for the femur were compared in terms of a fixed score for the innominate bone. It has been shown in the preceding section, however, that at the time of puberty whereas femoral scores differ little between early and late maturers, scores for the innominate bone differ considerably. For the within-sex analysis differences in score for the innominate bone were therefore studied in terms of a fixed score for the femur instead of *vice versa*. Table 3 shows the distribution of innominate bone maturity scores of the 51 girls who at the age of 12 years had the same maturity score for the femur (14 points) but differed in age of menarche. Among those who had already passed or were within 6 months of the menarche 44% (11 out of 25) had a score of 17 points or more for the innominate bone whereas only 4% of girls (1 out of 26) whose menarche was still more than 6 months off had as great a

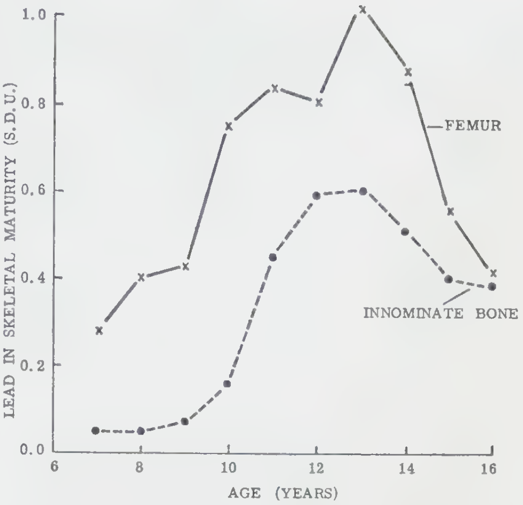


Fig. 4 Lead in skeletal maturity of girls whose menarche occurred before the age of 12½ years over girls with later menarche, by chronological age. The two scores have been reduced to a common scale by expressing each difference in terms of the corresponding standard deviation for all girls of known age at menarche.

TABLE 3

Distribution of maturity score for innominate bone among girls aged 12 who had comparable maturity for the femur but differed in age at menarche

Age at menarche	Innominate bone maturity score (points)			Total
	15 or less	16	17 or more	
$<$ 12½ years	1	13	11	25
$\geqslant$ 12½ years	11	14	1	26
Total	12	27	12	51

$\chi^2_{(2)} = 15.890$; $P < 0.001$.

TABLE 4

Distribution of femur maturity score on last birthday preceding menarche in early and late maturing girls

Age at menarche	Femur maturity score (points)			Total
	13 or less	14	15 or more	
$<$ 12½ years	10	34	6	50
$\geqslant$ 12½ years	3	28	18	49
Total	13	62	24	99

$\chi^2_{(2)} = 10.331$; $P < 0.01$.

pelvis score. This is clear evidence that there is constitutional variation within a sex in the sequence of ossification in addition to that already shown between the sexes. A further within-sex analysis of skeletal maturation patterns is shown in table 4 where the relationship between the state of development of the femur at menarche in early maturing girls is compared with that in late maturing girls. It can be seen that on the last birthday preceding their menarche only 12% of “early” girls had a femur score of 15 or more, compared with 37% for other girls. If we assume that the more mature a bone is the less it will grow, and the recent studies of Noback, Moss and Leszczynska (’60) suggest we are justified in doing so, then the relatively immature state of their epiphyses at the time of puberty will permit “early” girls to achieve a larger spurt in longitudinal growth than other girls. This state of affairs is different from the between-sex comparison made in section 3 above, where it was shown that when boys as a whole at a given stage of maturation of the innominate bone are compared with girls a a whole at the same stage, the state maturity of the femur differs little. Ev dently, therefore, the amount of growth be undergone by the two sexes is simila although the boys are already taller. Th greater adult height of men thus owe much to the fact that the culminatin phase of growth in boys is “deferred” b about two years. In the pre-pubertal yea boys have, if anything, a smaller growt rate with respect to time than girls, bu much the larger growth rate with respe to maturation of the long bones. In th present study it was found that at the stag of long-bone development indicated by femur score of 8 points (in the averag girl just after age 7 years) the sexes a ready differed in mean height by no les than 114 mm (4½ ins.). The relationshi between rates of maturation and growth a puberty is dealt with in more detail in subsequent paper (Hewitt and Acheso ’61).

DISCUSSION

Skeletal maturation ought not to b thought of as one homogeneous and stead process. It is quite normal for health children to differ in the sequence as well a the overall rate of ossification. It is als quite normal for a healthy child to underg changes in rate of maturation as it does i rate of growth, particularly at the time o puberty. For these reasons the concept o “skeletal age” and the associated method o assessing maturity by comparison wit Atlas standards cannot be altogether vali Skeletal maturation is evidently dependen on several factors; a study of the hi region alone implies that there must be a least three:

(A) one which fosters rate of matura tion of the femur, and with which girls a a whole are more generously endowed tha boys;

(B) one which is responsible for th pre-pubertal phase of pelvic maturatio and which is equally distributed betwee the two sexes;

(C) one which first manifests itself a puberty, to which the bones of the pelvi are much more responsive than those o the femur.

Presumably these are genetically determined and the suggestion that such fac ors produce important variations in the pattern as well as the rate of skeletal maturation runs contrary to Todd's ('37) teaching on this subject, and to the thesis upon which he based his Atlas. The suggestion is nevertheless by no means new, for it was first put forward more than 50 years ago by Pryor ('08), and supported by his own and Buschke's studies of homozygous and heterozygous multiple births (Buschke, '34; Pryor, '39) as well as by subsequent, more extensive work both on children less closely related (Sontag and Lipford, '43; Reynolds, '43; Hewitt, '57) and on bilateral asymmetry of skeletal maturation in healthy children (Baer and Durkatz, '57). Genetic factors are not, of course, the only source of variations in ossification pattern. Despite his observation that "determinators of maturity do not always make their appearance in the same order in male and female" Todd ('37) did not feel any need to postulate an inborn difference between the sexes in this respect. Rather the differences in pattern were to be explained in terms of two contingent circumstances; first, that certain centers of ossification are more to be delayed by reason of ill-health or other environmental adversity, and second, that boys are more liable to such disturbances than girls. Todd was even inclined to believe that the sex-difference in *rate* as well as in pattern was due to the greater susceptibility of the male to environmental influences on physical development. This last view finds no adherents today, but the other two suggestions have been borne out by several investigations. The most recent and convincing of these was conducted by Dreizen, Snodgrasse, Webbpeploe and Spies ('58), who compared the skeletal maturation of a group of under-nourished Alabama children with the well-nourished Cleveland children on whom the Greulich-Pyle Atlas was based. It was found that the boys of the under-nourished group were more profoundly retarded than the girls, but that both were significantly backward; also that the liability of individual bony centers to be retarded varies both between and within sexes. Thus, in addition to the reduction of rate, the pattern of skeletal maturation must also necessarily have been affected by environmental adversity. Many other workers (Abbott, Townsend, French and Ahmann, '50; Weiner and Thambipillai, '52; Beresowski and Lundie, '52; Berridge and Prior, '54; Jones and Dean, '56) have come to parallel conclusions. Yet the disruptive effect of the environment tends to be over-emphasized, for in these studies the children were, for the most part, exposed to a considerable degree of malnutrition.

In what is probably the largest published study of skeletal maturation in relation to health (Hewitt, Westropp and Acheson, '55) episodes of sickness in a group of adequately nourished Oxford children appeared to retard maturation very little, and the effect was too small for technical significance even in the aggregate of 2,296 life-years. Compared with the effects of ill-health on growth and on the incidence of transverse scars in the metaphyses of the long bones, the slowing of skeletal maturation was slight — a conclusion previously drawn by Grande and Rof ('44) from their observations of a group of poorly-nourished Spanish children. Moreover, within the hand, the apparent effect (on the Oxford children) was *less* for epiphyses than for carpal bones, a finding which has since been confirmed (Dreizen, Snodgrasse, Webbpeploe and Spies, '58).

Variations in pattern due to such environmental causes as malnutrition and systemic illness are presumably induced centrally by some alteration in hormonal secretion (Acheson, '60). It is not possible to say, however, the extent to which the genetically determined variations are brought about by differences in hormonal secretion and how far by differences in target (i.e., cartilage) sensitivity.

Differences in the pattern of skeletal maturation, such as those which have been shown above to exist between boys and girls and between girls who reach the menarche at different ages, have previously been reported for boys of contrasted adult physical type (Acheson and Dupertuis, '57). In the rhesus monkey (*Macaca mulatta*) also Wagenen and Asling ('58) have demonstrated a very definite sex-difference in the pattern of epiphyseal fusion. For instance, fusion of the triradiate cartilage occurs about 6 months earlier in the female than in the male, but fusion of the distal epiphysis of the femur occurs more than

18 months earlier in the female — a sex difference similar in type to that described in the children of the present study. The ubiquity of these pattern variations lead us to stress again that although Atlases of "skeletal age" are useful for making a quick assessment of the status of a child, the standards are not equally applicable to all children. Their value is limited in particular when ill or underprivileged populations are being studied, or when precise assessments of skeletal maturity are being made for scientific purposes.

SUMMARY

1. Study of the existing publications from the Brush Foundation investigations suggested that in both the hand and the knee skeletal maturation proceeds at an accelerated rate before puberty. This "spurt" occurs earlier in girls than boys, and also earlier in girls who reach menarche before the thirteenth year than in those who reach it later.

2. The skeletal maturity of 400 Brush Foundation children (225 boys, 175 girls) was re-assessed from radiographs of the innominate bone and head of the femur by the Oxford Method.

3. Analysis of annual increments (velocity curve) for the hip joint and pelvis showed for both sexes an infantile phase of rapid development, a period of slower development in mid-childhood, and a pubertal acceleration, earlier in girls than boys, but in both sexes leading to a prominent peak.

4. There is no between-sex difference in rate of maturation of the innominate bone up to age 10 years, but the head of the femur in girls maintains a definite and constantly increasing lead over boys from the appearance of the first maturity indicator until shortly before growth ceases.

5. Relative to the innominate bone the epiphyses at the head of the femur mature significantly more rapidly in pre-pubertal girls than in pre-pubertal boys.

6. There is an increasing correlation between hip maturity score and the age of menarche as girls grow older rising from $r = -0.2$ for 8 and 9 years to $r = -0.7$ for 12 and 13 years. The correlation then falls again. The biggest contribution to this correlation is the score for the innomina
bone.

7. Relative to the innominate bone, t
head of the femur is significantly less m
ture at menarche in girls who reach th
stage of sexual development early than
is at menarche in those who reach it late

8. It is concluded that these differenc
in rate and in pattern are genetically d
termined and it is pointed out that sin
they occur within a sex as well as betwe
sexes, they make the skeletal age tec
nique an unsatisfactory method for asse
ing the maturity of the hip joint a
pelvis.

ACKNOWLEDGMENT

It is a pleasure to acknowledge the i
spiration given to this research by the la
Dr. Normand L. Hoerr. During the ti
one of us was working on the Bru
Foundation material in his department
devoted many hours to friendly discussi
of the problems we have touched on he
and before his death he released the da
so that we could undertake this analys
and publish the results. We are gratef
too to Dr. A. M. Stewart for her criticis
of the work at a later stage. R.M.A. was
receipt of personal grants from the Roc
feller Foundation and from the Radcli
Trust, Oxford.

LITERATURE CITED

Abbott, O. D., R. O. Townsend, R. B. French a
C. F. Ahmann 1950 Carpal and epiphys
development; another index of nutritional sta
of rural school children. Amer. J. Dis. Chi
79: 69–81.

Acheson, R. M. 1957 The Oxford Method
assessing skeletal maturity. In: Clinical Ort
paedics, *10:* 19–39.

——— 1960 Effects of nutrition and dise
on growth. In: "Human Growth." Sympo
Soc. Hum. Biol., Vol. *3:* 73–92.

Acheson, R. M., and C. W. Dupertuis 1957 T
relationship between physique and rate
skeletal maturation in boys. Hum. Biol.,
167–193.

Baer, M. J., and J. Durkatz 1957 Bilate
asymmetry in skeletal maturation of the ha
and wrist. Amer. J. Phys. Anthrop., *15:* 1
196.

Beresowski, A., and J. K. Lundie 1952
quence in the time of ossification of the car
bones in 705 African children from birth to
years of age. S. Afr. J. med. Sci., *17:* 25–31

Berridge, F. R., and K. M. Prior 1954 T
skeletal development of a group of the child
at the beginning and end of the period of
perimental feeding. Spec. Rep. Ser. med. R
Coun. (London.), No. 287: 119–129.

Buschke, F. 1934 Röntgenolische Skelettstudien an menschlichen Zwillingen und Mehrlinger. Fortschr. Röntgenstr., (Erg.Bd.), *46*.

Dreizen, S., R. M. Snodgrasse, H. Webbpeploe and T. D. Spies 1958 The retarding effect of protracted undernutrition on the appearance of the post-natal ossification centers in the hand and wrist. Hum. Biol., *30:* 253–264.

Grande, F. C., and J. C. Rof 1944 Alimentación y desarrollo infantil. Rev. clin. esp., *12:* 234–240.

Greulich, W. W., and S. I. Pyle 1950 Radiographic atlas of skeletal development of hand and wrist. 1st edn. Stanford, California. Stanford University Press.

——— 1959 Radiograph atlas of skeletal development of hand and wrist. 2nd edn. Ibid.

Hewitt, D. 1957 Some familial correlations in height, weight and skeletal maturity. Ann. Hum. Genet., *22:* 26–35.

Hewitt, D., and R. M. Acheson 1961 Some aspects of skeletal development through adolescence. II. The inter-relationship between skeletal maturation and growth at puberty. Amer. J. Phys. Anthrop., *19:* 333–344.

Hewitt, D., C. Westropp and R. M. Acheson 1955 Oxford Child Health Survey. Effect of childish ailments on skeletal development. Brit. J. prev. soc. Med., *9:* 179–186.

Jones, P. R. M., and R. F. A. Dean 1956 The effects of Kwashiorkor on the development of the bones of the hand. J. Trop. Pediat., *2:* 51–68.

Moss, M. L., and C. R. Noback 1958 A longitudinal study of digital epiphyseal fusion in adolescence. Anat. Rec., *131:* 19–32.

Nicolson, A. B., and C. Hanley 1953 Indices of physiological maturity. Child Dev., *24:* 3–38.

Noback, C. R., M. L. Moss and E. Leszczynska 1960 Digital epiphyseal fusion of the hand in adolescence: a longitudinal study. Amer. J. Phys. Anthrop. N.S., *18:* 13–18.

Pryor, J. W. 1908 Order of ossification of the bones of the human carpus. Bull. State College Kentucky, *1:* No. 2.

——— 1939 Normal variations in the ossification of bones due to genetic factors. J. Hered., *30:* 249–255.

Pyle, S. I., and N. L. Hoerr 1955 Radiographic atlas of skeletal development of the knee. Charles C Thomas, Springfield, Ill.

Reynolds, E. L. 1943 Degree of kinship and pattern of ossification. Amer. J. Phys. Anthrop., N.S., *1:* 405–416.

Shuttleworth, F. K. 1937 Sexual maturation and the physical growth of girls age 6–19. Monogr. Soc. Res. Child Developm., *3:* No. 3.

——— 1938 Sexual maturation and the skeletal growth of girls age 6–19. Ibid., *3:* No. 5.

Simmons, K. 1944 The Brush Foundation study of child growth and development. Part 2: Physical growth and development. Ibid., *9:* no. 1.

Simmons, K., and W. W. Greulich 1943 Menarcheal age and the height, weight and skeletal age of girls age 7 to 17 years. J. Pediat., *22:* 518–548.

Sontag, L. W., and J. Lipford 1943 The effect of illness and other factors on the appearance pattern of skeletal epiphyses. J. Pediat., *23:* 391–409.

Tanner, J. M. 1955 Growth at Adolescence. Oxford: Blackwell Scientific Publications.

Tanner, J. M., M. J. R. Healy, R. D. Lockhart, J. D. Mackenzie and R. H. Whitehouse 1956 Aberdeen Growth Study. I. The prediction of adult body measurements from measurements taken each year from birth to 5 years. Arch. Dis. Childh., *31:* 372–381.

Todd, T. W. 1937 Atlas of skeletal maturation (Part I. Hand). St. Louis: Mosby.

van Wagenen, G., and C. W. Asling 1958 Roentgenographic estimation of bone age in the rhesus monkey (*Macaca mulatta*). Amer. J. Anat., *103:* 163–185.

Weiner, J. S., and V. Thambipillai 1952 Skeletal maturation of West African negroes. Amer. J. Phys. Anthrop., *10:* 407–418.

Some Aspects of Skeletal Development Through Adolescence

II. THE INTER-RELATIONSHIP BETWEEN SKELETAL MATURATION AND GROWTH AT PUBERTY

DAVID HEWITT[1] AND ROY M. ACHESON[2]
Department of Social Medicine, University of Oxford, England, and Department of Social and Preventive Medicine, Guy's Hospital Medical School, London, England

In the previous paper (Hewitt and Acheson, '61) we showed that a definite pubertal spurt occurs in the maturation of the hip joint, and especially the innominate bone; we also inferred from the work of other authors (Todd, '37; Pyle and Hoerr, '55) that a similar spurt occurs in the hand and to a lesser extent in the knee. It is the purpose of the present communication to examine the relationship between this increase in the rate of maturation and other developmental phenomena at puberty, in particular the increase in rate of stature gain.

MATERIAL AND METHOD

Assessment of skeletal maturity and stature

The analysis is based on the same group of Brush Foundation children as was described in part I, and the skeletal maturity assessments are again those from radiographs of the hip joint and innominate bone[3] by the Oxford Method (Acheson, '57). The measurements of standing height were taken in stocking soles when the children attended for radiography at birthdays and "half-birthdays" to the age of 5 years, and thereafter annually. An adult height was also available for 128 of the boys who were recalled for special study after the main work of the Brush Foundation Study had been completed (Dupertuis and Michael, '53). In addition to our own data we shall make frequent reference to the analysis of Brush Foundation material made by Simmons ('44).

Use of directly estimated accelerations

Child development studies usually provide for the taking of measurements at regularly spaced ages. The resulting growth data are conventionally reported both in terms of the age-specific measurements themselves and, provided the study is of the "longitudinal" type, in terms of the first differences of these measurements (the increments or "velocities"). The value of recording increments for individual children is, first, that this provides ranges of normal growth rate (as distinct from total size), and second, that it aids the description and analysis of growth processes, particularly those of adolescence. In this latter use, however, *changes* in growth rate, that is, *second* differences of the original measurements, are of central interest, rather than growth rate itself. For instance, Shuttleworth ('37) and others have attempted to define classes of children with relatively early or late puberty on the basis of their "age of maximum growth." By this is meant the first (post-pubertal) age at which an increment was succeeded by a smaller increment, in other works the age at which growth decelerated. But if hypotheses concerning acceleration are to be discussed and tested objectively it is clearly desirable to employ numerical values of acceleration for individual children. This has been done at certain stages of the following study, where estimates of acceleration have been derived in the following simple way. If the measurements of a single child at (say) ages 1, 2 and 3 were y_1, y_2 and y_3, then the acceleration at age 2 has been estimated as $(y_3 - 2y_2 + y_1)$. The chief advantages sought from these estimates are first, that they enable one to apply objective significance tests to apparent changes in growth rate instead of having to judge these subjectively from the shape of increment curves, and second, that they help to locate the time of onset of the pubertal changes in growth rate. Their chief disadvantages are that they can make no use of any measurement which is not one of a set of three, equally spaced in time; and that the component of variance of the acceleration arising from errors of measurement and recording is three times as great as in the case of simple increments and 6 times as great as in the original measurements.

---

[1] 8, Keble Road, Oxford, England.

[2] Guys Hospital Medical School, London S. E. 1, England.

[3] The less clumsy, but less accurate term "pelvis" is used at various places in the following text.

TABLE 1

Acceleration (mm per year per year) of gi growth in height, at ages defined in relation to the birthday immediately preceding the menarche

Age in years in relation to birthday preceding menarche	Number of girls	Acceleration	
		Mean	Standar deviatio
−6	30	− 1.83	16.48
−5	35	− 6.00	17.39
−4	42	+ 1.79	17.28
−3	44	− 3.64	15.26
−2	50	+ 2.24	16.15
−1	53	+11.02	20.09
0	55	−22.73	22.44
+1	43	−29.21	18.46
+2	36	−14.47	14.61
+3	34	− 8.71	12.24

ANALYSES AND FINDINGS[4]

1. *Timing of pubertal height acceleration in relation to the menarche*

As table 1 shows, it is possible to use acceleration values to estimate the time interval between the age of the major pubertal acceleration of linear growth and the age of menarche. Means and standard deviations are given for height accelerations of girls at 10 ages measured in years before (−) or after (+) the birthday immediately preceding the menarche, which is designated as age 0. Over the range −6 to −2 none of the mean accelerations is significantly greater than zero, but t mean of +11.02 at age −1 is significant greater than zero and also significant greater than the mean acceleration f the previous birthday at age −2. At age that is, on a day between 0 and 12 mont before the menarche, the mean acceler tion is large and negative. Hence the ti

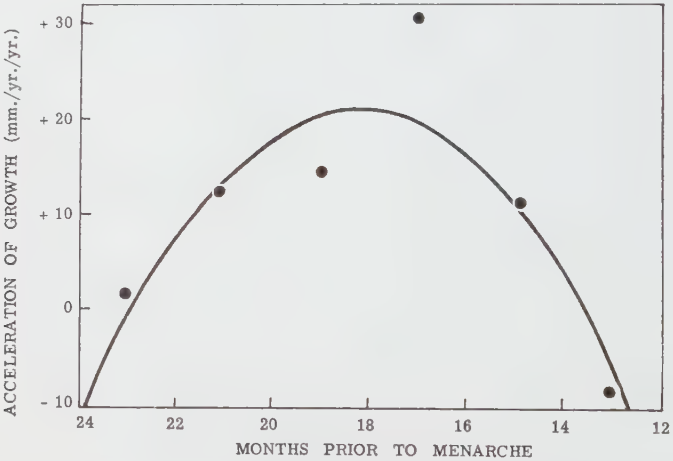


Fig. 1 Mean accelerations of standing heights at various ages defined in relation to age at menarche.

---

[4] This section does not lend itself to the simp tabulation of processed data which are usua catalogued under Results. It takes the form of series of analyses each following logically fro the one before, and where possible carried in close parallel with the earlier work of Si mons ('44) on the same material. In order help the reader, the hypothesis which an analy is designed to establish is printed in italics.

nterval we are trying to estimate must ie between one and two years. This crude stimate can be greatly refined by taking nto account the precise ages in months at which the menarche occurred. When he 53 girls for whom acceleration values were available at age 0 were divided into 6 groups (those whose menarche occurred at +0 or +1 month, at +2 or +3 months, etc.), the differences between their mean accelerations were found to be significant ($P < 0.01$), and also to be obviously systematic, with a maximum within the range. This can be seen clearly in figure 1 where the 6 means are plotted together with a parabola fitted by the method of least squares. The index of correlation associated with this curve is moderately large ($\rho = 0.49$) and the residual intergroup variation is not significant ($P > 0.20$). The curve passes its maximum at 18.2 months, so the average interval between the major pubertal height acceleration and menarche may be taken to lie between about 17 and 19 months. This is a very much shorter interval than the three years judged by Shuttleworth ('37) from height increment curves. However, Shuttleworth's concern was with a slightly different time-interval, namely that between the menarche and what he called the "second inflection point" of the height curve. This would not correspond exactly with the interval estimated here unless, in a given child, the whole of the pubertal height acceleration could be regarded as operating at a single point in time. In fact, as Shuttleworth's ('38) own later work suggested, there is almost certainly some "staggering" of the accelerations in the various segments of the body which contribute to total standing height, and this would make the interval estimated here somewhat shorter than his ('37) estimate. A difference between the two estimates as large as 18 months would not, however, be expected unless the onset of the component accelerations were spread over *at least 18* months.

Another subdivision of the same 53 girls provides objective confirmation of Shuttleworth's ('37) view that early-maturing girls undergo a more intensive acceleration of growth, thus partly compensating for the fact that they are on average smaller than other girls when they reach puberty. When the 53 girls are ranked in order of age at menarche it is found that the first 26 (up to 12 years 5 months) had an average acceleration at the −1 birthday of +18.04 compared with only +4.26 for the remaining 27 (12 years 6 months later). The technical significance of this difference is not in doubt ($P < 0.02$) and the difference itself so large (factor of more than 4 to 1) as to show that the postulated mechanism must be very powerful. It was suggested in part I of this paper (Hewitt and Acheson, '61) that this greater acceleration may be made possible for the "early" girls by virtue of the fact that at the onset of puberty the epiphyses of their long bones are at a relatively immature stage of development.

2. *Timing of skeletal maturity acceleration in relation to the menarche*

An analysis parallel to that shown in table 1 for height was applied to the total maturity scores for the hip joint and innominate bone, and the mean accelerations at 8 of the same ages are shown in figure 2. In this figure the histograms represent means based on data classed by whole years before or after the birthday immediately preceding the menarche. For example, the first one represents the 37 girls for whom hip films were available at

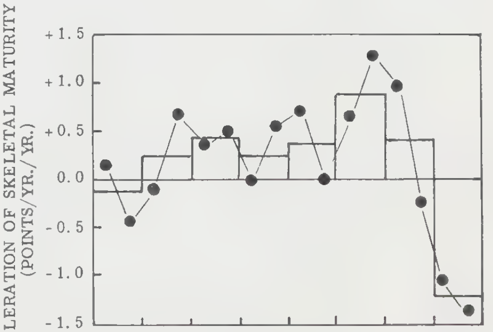


Fig. 2 Mean accelerations of total skeletal maturity score for head of femur and innominate bone at various ages defined in relation to age at menarche.

birthdays −6, −5 and −4, the pivotal age of −5 lying between 5 and 6 years before the menarche. Each such group was also subdivided according to whether menarche occurred more or less than 6 months after the last pre-menarcheal birthday (0 on the horizontal axis), and the mean accelerations for these sub-groups are marked by the black dots.

It will be seen that, on average, the total hip score was positively accelerated in each of the 5 years preceding menarche, and also in the first year after it. Changes which are technically significant ($P < 0.05$) also occurred within as well as between years: in the 5th pre-menarcheal year (from negative to positive) and in the year of the menarche itself (positive to negative). Clearly the pubertal acceleration of skeletal maturity is spread over a much longer period than the acceleration of height. Indeed it is hardly possible to regard it as a single acceleration, particularly in view of evidence presented in part I that maturation in the femur and in the innominate bone respond quite differently to the advent of puberty. Analyses like those summarized in figure 2 were therefore carried out for the femur and pelvis scores separately. The innominate bone alone underwent a greater mean acceleration at age −1 than at any other birthday, a result which is closely similar to that for height acceleration. In the case of the femur there were two separate birthdays at which acceleration was significantly positive (−3 and 0) while at age −1, when acceleration of the pelvis score was greatest, there was suggestive evidence (P approximately 0.06) of *de*celeration in the femur score. The fact that the femur *score* accelerates twice cannot, however, be taken to prove that the *process* of maturation in the femur is itself subject to separate accelerating stimuli; the reason is that the method of assessment records a number of discrete stages, so that what is essentially a smooth process appears to move in jerks. These tend to be eliminated when aggregate scores for several indicator series are taken together; they could, however, give rise to apparent small changes in rate which are, in effect, artefacts.

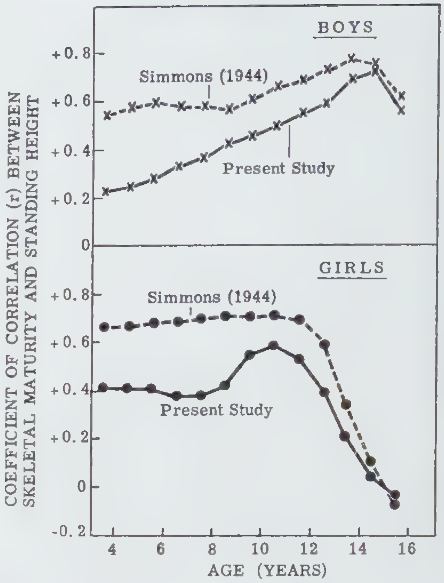


Fig. 3 Age trend of the correlation betwee skeletal maturity and standing height for boy and girls. Each plotted point represents the mea of the estimated height-maturity correlations a two successive birthdays.

3. *Effect of puberty on the relation between skeletal maturity and height*

We have shown in the foregoing se tions that skeletal maturation undergoe an acceleration concomitant with th growth acceleration of puberty. It is, hov ever, well-known that in the pre-pubert period there is a relationship between th rate of skeletal maturation and the rat of linear growth so that children who ar relatively mature for their age tend also t be relatively tall.[5] Therefore, if skeleta maturation does in fact undergo an acce eration, concomitant with the acceleratio in growth, *the intensity of the relationshi between stature and skeletal maturit should be increased after puberty.* Figur 3 shows graphically a correlation analysi between stature and maturity and it ca be seen that the present results for girl conform perfectly with this hypothesis The correlation is obviously stable a about +0.4 from the fourth to the eight years, after which it rises to a level a most 50% higher before entering on the declining phase common to both analyses. The results for boys do not confirm the prediction because the correlation shows a continuously rising trend from the 5th year of life onwards, which must be caused by factors present long before the onset of the general pubertal accelerations. The crosses plotted for the 14th and 15th years are, however, higher than would be obtained by an extrapolation of the previous trend, and this is at least consistent with expectation. It will be noted also that, although the boys' correlation in the present analysis starts at an appreciably lower level than the girls', it eventually reaches a higher peak. This sex difference, which implies that the factors responsible for co-ordinating the growth and maturation of the skeleton are not the same in the two sexes, is the only respect in which our analysis confirms a similar one carried out by Simmons ('44) on the Brush Foundation material (table 61) for she failed to show any increase in correlation between height and "skeletal age" during or after puberty.

---

[5] This lead in height is not, as will be show in section 5, fully commensurate with their ac vancement in skeletal maturity.

There are two possible reasons for the difference between the two analyses. In the first place, as we have already shown in part I (Hewitt and Acheson, '61), the "skeletal age" scale must be "stretched" in the region of puberty and therefore the systematic part of the scatter artificially reduced. Secondly, since Simmons' "skeletal age" values were derived as the mean of assessments in 6 separate areas (hand, foot, elbow, knee, hip and shoulder), a pattern of the type we have postulated would be obscured by any tendency for the pubertal acceleration to occur at different ages in different parts of the skeleton.[6] It is also quite possible that the bones of the hip region really are subject to a more powerful acceleration than those of the other areas contributing to Simmons' average: in this connection it has already been shown in part I of this paper (Hewitt and Acheson, '61) that there is probably less acceleration in the knee than in the hip or hand.

Another obvious difference between the results of the two analyses presented in figure 3 is the lower level of correlation at all ages found in the present study. This is almost certainly due to the use of hip assessments alone in place of averaged assessments for several areas of the skeleton. Both the growth and maturation of any one particular part of the skeleton must be determined by factors which have less influence (or none) on the development of other parts. Hence the hip film alone cannot be expected to contain so much information about the aggregate of maturational processes associated with gain in total height.

With the possible exception of the knee, where much of the growth of the lower limb occurs, it is unlikely that the maturity indicators of a given area will all be equally relevant to the rate at which stature increases. In the hip region, as was shown in part I, pre-pubertal scores for the pelvic indicators do not differentiate boys from girls or girls with relatively early sexual maturity from other girls. *It is therefore reasonable to suppose that the pre-pubertal pelvis scores might contribute less to the correlation between maturity and height than the scores for indicators in the femur.* A formal test of this hypothesis would require a partial correlation analysis for which the data at present available are not suitable, but verification is to be found in a simple comparison of some mean heights. Thus, among 99 girls who were both measured and assessed at age 10, the 69 most advanced in femur score averaged 49.9 mm taller than the remainder, but the 67 most advanced in pelvis score averaged only 27.3 mm taller than the remainder, and if allowance were made for the inter-correlation between these two scores the contrast in *net* association with height would be even greater. After puberty the position is reversed: a similar division of 51 girls aged 14 showed that those with a relatively advanced femur score were only 11.0 mm taller than others, while a comparable classification by pelvis score yielded a height difference of 29.3 mm.

---

[6] Data from another part of the same monograph (Simmons, '44) suggest that there are such differences. The object of averaging assessments from different areas was to increase the reliability of the estimates of "skeletal age," i.e. to reduce the element of observer error, an object which was no doubt achieved. But if this had been the only effect of the averaging then the standard deviations based on the mean of 6 areas should have been considerably smaller than the standard deviations based on single areas. In fact the available comparisons (tables 59 and 60) show surprisingly little reduction in scatter consequent upon averaging, while in some cases there was an increase.

An interesting corollary of these findings is that the sex difference in total growth potential (for definition see Acheson and Hewitt, '54) must be brought about in a rather special way. For if it were due to the same causes as variation on growth potential among girls, then 10-year-old girls should average at least 50 mm taller than 10-year-old boys. Simmons' data for the Brush children as a whole ('44, tables 10 and 11) show in fact a sex-difference in height of less than ½ mm at this age. The "extra" maturation achieved by girls would be attributed to a factor which has little or no influence on growth rate, or alternatively, boys could be endowed with a comparative excess of some growth factor having little influence on maturation. It will be shown in the discussion below that, since the total growth rate of pre-pubertal boys is not greater than that of girls, this sex-difference may well be due to the higher titre of testosterone in the pre-pubertal male.

4. *Relationships between the height and maturity accelerations*

Timing of accelerations. It has been shown above and in part I that skeletal maturation (particularly in the innominate bone) is subject to pubertal acceler tion of a kind similar to that recogniz in skeletal growth; the question now aris as to how far acceleration along these tw paths of development is attributable the *same* hormonal influences. Direct e dence on this question can only be c tained from the fields of endocrine path ogy and therapeutics, but on grounds biological economy it seems reasonab to suppose that in each case the acceler tion represents a response to substantial the same stimuli. If so, *there should be characteristic time interval between t growth-response and the maturation-r sponse,* just as there is a characterist interval between the menarche and t main height acceleration in girls. In ord to test this hypothesis it was necessary choose a stage which could be taken an indication that the accelerated pha of skeletal maturation was about to sta The stage chosen was the attainment its 16th point by the innominate bone, b cause, as shown in our previous pap (Hewitt and Acheson, '61, fig. 2(b)), th was the stage at which the girls' skele maturity accelerated away from the boy and it also was when the boys in th turn reached this stage that they beg to reduce the female lead.

Estimates were therefore made of t mean height acceleration at various bir days defined in relation to the age wh this 16th point was attained, and thr of these are shown for each sex in colur A of table 2. Considering the results f

TABLE 2

Mean height acceleration (mm per year per year) in 36 boys and 59 girls at ages defined in relation to attainment of the sixteenth point of maturity score for the innominate bone, sexes separately

	Age relative to that on attaining sixteenth point for the innominate bone	A "Observed" mean acceleration	B "Expected" mean acceleration	Difference (A − B)
	Boys			
X	Two birthdays (12 to 24 months) before	+ 7.52	+ 5.26	+ 2.26
Y	One birthday (0 to 12 months) before	+22.42	+ 2.17	+20.25
Z	One birthday (0 to 12 months) after	−20.68	−16.02	− 4.66
	Girls			
X	Two birthdays (12 to 24 months) before	+ 4.91	+ 0.83	+ 4.08
Y	One birthday (0 to 12 months) before	+ 4.86	− 3.36	+ 8.22
Z	One birthday (0 to 12 months) after	−17.15	− 9.45	− 7.70

boys first, it is clear that acceleration is much greater in the vicinity of the birthday immediately preceding the chosen maturity stage (Y) than in either of the other 12-month periods shown in the table (X and Z). On the grounds of the chronological ages represented at birthday Y alone, a positive mean acceleration would have been expected (see column B). But the observed mean exceeds that expected by 20.25 mm and this is more than 4 times the standard error of the difference. The absolute value is so high as to suggest that boys have a true maximum height acceleration near the middle of the period 0 to 12 months before attaining their 16th pelvis point. During this same period the girls' mean acceleration is also significantly ($P < .01$) greater than the age-based expectation, but it is not large in relation to the mean for the preceding 12-month period (X), or even in relation to the mean of +7.01 mm found for all girls at their 10th birthday regardless of maturity stage. The alternative explanations are therefore, either that in girls there is less overlap between the factors responsible for acceleration of height and of maturity than in boys, or that in girls the attainment of the 16th pelvis point is a less efficient indicator of the time of maturity acceleration.[7]

Size of accelerations. Further analysis showed that early arrival at pelvis point 16 was associated with a relatively large acceleration of growth, a finding which parallels that obtained in section 1 of the present paper when the relationship between growth acceleration and age at menarche was examined. The first 29% of girls (17 out of 59) to score 16 pelvis points had a mean acceleration of +10.9 mm compared with +2.4 mm for the remainder. Among boys the first 25% (9 out of 36) to reach this stage had a mean acceleration of +32.0 mm compared with +19.2 mm for the remainder. Evidently, in both sexes, the earlier the developing tissues are exposed to the full hormonal stimuli of puberty, the more vigorously they can respond. In teleological terms it may be said that boys as well as girls tend to be "compensated" for early arrival at puberty.

5. *The balance between maturation and linear growth: final height*

If growth rate and maturation rate were inherited quite independently of one another, children with a rapid rate of maturation would tend, as adults, to be distinctly short, while those with a rapid rate of growth would tend to be tall. The interrelationship between the factors determining these rates must therefore have the effect of limiting the amount of variation in the stature of the adult population. Direct evidence on the extent to which the effect of rapid maturation is balanced by correspondingly rapid growth, or slow maturation by slow growth, is necessarily scanty because it can only be obtained from individuals observed during childhood and again when growth has unquestionably stopped. However, the complete balancing out would seem to require a more intense correlation between rates of growth and of maturation than is usually found. We therefore postulate that *the fast maturing child will be a much smaller adult than the slow maturing child.*

(a) *Fast and slow maturers before the growth spurt.* The data of Simmons ('44)[8] show that among 6-year-old boys, a lead of one year in "skeletal age" is associated with a lead in height of 35.5 mm on average, whereas a year's growth in height at this age may be estimated to average 65.7 mm (half the difference between the means for ages 5 and 7 years). Hence the "extra" growth achieved by rapid maturers covers little more than half of the height handicap incurred by the shorter period of growth available to them, and similar results are obtained for a number of other ages in both boys and girls. If there were no subsequent compensating mechanism one would therefore expect adults who stopped growing a year before the average for their sex to be about 30 mm below average height.

---

[7] The method here employed for identifying the usual interval between height and maturity accelerations is not quite the most efficient that could be devised, even when measurement of height and maturity is spaced at the long (for this purpose) interval of 12 months. An aggregate score such as 16 pelvis points can be made up in a variety of ways because all individuals do not follow the same sequence of ossification. An attempt was therefore made to define the moment of maximum maturity acceleration in terms of individual indicator series, but the analysis proved too complex to be of much value.

[8] The standard deviations and correlations necessary for estimating the regression of height on "skeletal age" at fixed chronological age are to be found in tables 10, 11, 59 and 60.

(b) *Fast and slow maturers after the growth spurt.* A number of Brush Foundation boys whose hip and pelvis films are included in the present study had been re-examined at the age of 20 years or over (Dupertuis and Michael, '53). Among them there were 43 who could be classified on a basis of whether they had reached a score of 7 points for the indicator series "head of femur" before their 16th birthday (25 boys) or after it (18 boys). As adults (minimum age 24) the slower-maturing group averaged 37.7 mm taller than the faster-maturing group. Five boys who had not attained this score by their 17th birthday were eventually 59.7 mm taller than the average for the whole group. Not many of the girls had been measured as late as age 18 years, nor were there any subsequent follow-up data for them, but the small sample available showed an amount of variation similar to that among boys. Thus among 13 girls for whom femur scores at age 12 years had been assessed the following average statures were found at age 18 years: most precocious 4, 1,606 mm; middle 4, 1,631 mm; slowest 5, 1,661 mm. Hence in each sex there may be, within the normal range of rates of maturation of the femur, systematic differences in adult height of up to 50 mm.

Tanner and Healy (see Tanner, '55, table 7) using first appearance of pubic hair as a criterion of maturity in 188 army cadets aged 19–21 years came to a similar conclusion. Although it is also possible that some of these subjects had not reached their final adult height, they found the most precocious 19% were, on average, 17.2 mm shorter than the 13% who had matured most slowly, and that nearly all this difference was in leg length.

We must therefore conclude that the slow maturer does have some net advantage in final adult stature over the fast maturer. Many investigators have failed to make this observation because they ha stopped making their measurements t soon. For instance, Simmons ('44) wrc "girls" mean terminal height is no great than their "16-year-old mean," and, though several of the 18-year-old Bru Foundation girls mentioned above show no further growth (and some an appare decrease in height) after the age of 1 their *average* increment of height betwe 16 and 18 was +6.1 mm, which is mo than twice the standard error.

(c) *The rapid grower.* The obverse this finding is *that children with a rap rate of growth will, on average, becom tall as adults,* despite the fact that th tend to have a shorter period of growt No analysis along these lines has bee made from the Brush data but the la follow-up by Tanner, Healy, Lockhar Mackenzie and Whitehouse ('56) of t Aberdeen children studied by Low ('5 confirms this hypothesis. The comme made by these authors that rate of grow and adult size "seem practically ind pendent" refers only to rate of grow measured from birth, which in turn i volves reliance on measurements whic the authors themselves show to be of pa ticularly poor predictive value. Rate growth from *conception* to an age as ear as one year had a very definite positi correlation with adult height, howeve and this correlation was *not* merely due the fact that body-length at age one ye constitutes an appreciable fraction of tot adult body-length. It is easily shown th the growth of the Aberdeen children up age one year must have been positive correlated with the increment from a one year to maturity, because the correl tion between length at one year and adu height could not otherwise exceed t ratio between the one-year-old and t adult standard deviations. This ratio w only 0.47 for boys and 0.51 for girls, b the correlations were 0.65 and 0.70 r spectively. Unlike the slow maturer whose height superiority only manifes itself at the very end of the developme period, the height advantage of rapid growing children is apparent at all age and tall children do tend to become ta adults.

DISCUSSION

In the previous paper (Hewitt and Acheson, '61) we showed that at least three distinct factors must be involved in the skeletal maturation of the hip and pelvis region. In the pre-pubertal years linear growth seems to be closely associated with the factor which is responsible for maturation of the femur, and at puberty with that which causes an acceleration of maturation of the innominate bone. The third factor is responsible for ossification of the primary centers of the innominate bone, but does not seem to have close association with linear growth. Rapid maturation of the skeleton constitutes a handicap as regards final height attainment, but this is partially offset within each sex, by the overlap between the two factors which determine the rates of growth and maturation, and also by the tendency for children who reach puberty early to undergo a more intensive growth acceleration. As between the sexes, however, neither of these compensating mechanisms apply; the more rapid femoral maturation of girls is not accompanied by more rapid growth, nor does their earlier arrival at puberty entail a greater growth spurt.

Apart from variation in sensitivity of the bones themselves to central stimuli, the explanation of these phenomena presumably has to be sought in age and sex variations of hormonal secretion rates. In his admirable review of the endocrinology of adolescence Tanner ('55) considered that the available data were so scanty as to make his inferences "somewhat speculative." There are, nevertheless, a few firm facts to build on.

During pre-pubertal childhood the hormonal *sine qua non of* healthy osteogenesis, and therefore of skeletal maturation, is the secretion of thyroxine (Johnston and Maroney, '39 (a) and (b); Johnston, '41 (b); Asling, Simpson, Li and Evans, '54, etc.) and it is now accepted that protein-bound iodine (PBI) represents accurately "the concentration of circulating thyroid hormone with which tissues are in contact" (Acland, '58). Studies of the PBI indicate that the thyroxine level is high in early infancy and, with the possible exception of a slight and temporary rise at puberty, falls steadily throughout the developmental period (Danowski, Huff, Erhard, Price, Brown, Wirth and Stevenson, '52; Durham, Cooke, Lancaster and Man, '54; DePascale, '56). A comparison of PBI levels in healthy boys and girls has so far failed to establish any sex-differences (Acland, '59), but no carefully planned statistical analysis of pertinent data had yet been undertaken. For these reasons it seems improbable that thyroxine is primarily responsible for the marked acceleration in the rate of maturation which we have shown to occur in early adolescence, although it is possible that it accounts for the faster rate of maturation in pre-pubertal girls.

As a consequence of their studies of acromegaly and gigantism, Kinsell, Michaels, Li and Larsen ('48) evolved the hypothesis that whereas "childhood growth . . . is entirely referable to pituitary growth hormone . . . pubertal growth is induced by steroid growth-promoting factors from the gonads and probably from the adrenal cortex . . .". Subsequently research has done much to bear out this hypothesis, and to suggest that skeletal maturation at puberty may also be controlled by steroid hormones.

Of the hormones concerned, perhaps most is known about testosterone. The adult male eunuch, with his narrow shoulders, slightly effeminate pelvis and still unossified growth cartilage plates, rapidly acquires masculine physique on the administration of testosterone (Thompson and Heckel, '39 etc.). In such cases the male hormone initiates the ossification of the growth cartilage plates, and therefore ends the potentiality of the long bones for growth; it also seems to have a specific stimulating effect on the growth of the clavicle and possibly the innominate bone. In dwarfed children of both sexes (Sobel, '56; Hubble, '57(a); Sobel, Raymond, Quinn and Talbot, '56) and in oversized girls (Goldzieher, '56) testosterone has been shown to stimulate long bone growth also. In over 50% of Sobel's cases (Sobel et al., '56) the accelerating effect on skeletal maturation was greater than that on growth, and Goldzieher ('56) used a testosterone preparation in conjunction with oestrogens for the specific purpose of inducing epiphyseal closure. From these observations it can be concluded that testosterone is:

(i) capable of temporarily increasing the rate of long bone growth (even when pituitary somatotrophic hormone is lacking), and

(ii) the probable agent responsible for epiphyseal closure in the male, and possibly, as will be seen, in the female too.

The part played by oestrogens in skeletal development is less clear. Johnston ('41a) could find no evidence that they created a positive calcium or nitrogen balance in girls, from which he inferred that they were not concerned with the bone formation which is essential to growth and skeletal maturation; nor did Hubble ('57a and b) give them any place in his hormonal growth equation. Yet Goldzieher ('56) claimed that they accelerated epiphyseal closure without accelerating linear growth in oversize girls. Acheson and Zampa ('61) have found in a recent study of skeletal maturation in ovarian dysgenesis and Turner's syndrome, conditions in which the pre-pubertal growth spurt has been shown to be absent (van der Werff ten Bosch, '59), that 14 of 18 patients (78%) aged 16 to 27 had a skeletal age, assessed from the Todd '37 standards, of 13 to 14 years. The other 4 patients had mature hands but were all aged over 21 years, and had been receiving oestrogen therapy for at least three years whereas only one of the 18 immature patients had been treated for more than a few weeks at the time the hand x-ray was taken. These findings led to two conclusions; first an intact ovary would seem to be necessary for epiphyseal closure to be completed physiologically and second oestrogens given in therapeutic dosage may be capable of bringing about this closure. In the healthy female, however, it is not improbable that androsterone and other ovarian and adreno-cortical androgens may play a part in the later stages of skeletal maturation.

The observations and conclusions of Nathanson, Towne and Aub ('39, '41) as to the source and timing of the secretion of the sex hormones accord so well with the work of others on this subject (Dorfman, Greulich and Solomon, '37; Catchpole and Greulich, '43; Miller and Mason, '45; Hain, '47; Mellman, Bongiovanni a Hope, '59 etc.) and with our own prese findings that it is worth propounding the at some length. They made semi-lon tudinal studies of children and found th the output of both 17-ketosteroids a oestrogen began to rise in both sexes the 7th or 8th year of life, the form being slightly higher in boys. It was n until about a year before the seconda sexual characteristics began to appear th the titre of follicle stimulating hormo (FSH) in the urine rose, and very short after this there was a dramatic rise in t 17-ketosteroid excretion in the male a in the oestrogen and 17-ketosteroid exc tion in the female. They attribute t earlier production of both hormones both sexes to the adrenal cortex and not consider that a significant output tak place from the gonads until the FSH tit in the urine rises. Recently Brown ('58 using more refined methods, has co firmed in principle their findings wi regard to gonadotrophins, and has show that the ratio of FSH and interstitial c stimulating hormone (ICSH) probably d fers in the sexes during the pubert period.

Our finding that skeletal maturati begins to accelerate in both sexes so years before the secondary sexual cha acteristics appear would suggest that th process is sensitive to the increased acti ity of the adrenal cortex which Nathanso Towne and Aub ('41) postulated at abo the age of 8 years. The growth spu which preceded the menarche by abo 18 months, and seemed closely linked wi the acquisition of a skeletal maturity sco of 16 points for the pelvis in both sexe would appear to be fairly closely synchr nized with interstitial cellular activity the gonads of both sexes. Furthermor it is during this pubertal period when th gonadal hormones have been added those from the adrenal cortex that th incidence of benign and malignant *ne plasia* in bone is greatest (Price, '55, '58

In addition to the central hormonal fa tors, much of the pattern difference the response of the various parts of th skeleton at puberty must lie in the "ta gets" or the epiphyseal cartilages a growth cartilage plates themselves. Th spect of the problem will probably deend for its solution upon laboratory work n animals rather than upon observations n man.

SUMMARY

(1) This paper forms the second part f a study based on 400 Brush Foundation hildren. The data consist of records of ge at menarche; standing heights; and adiographs of the hip joint and innomiate bone assessed for maturity by the Oxford Method.

(2) It is shown that in girls the puberal acceleration of stature gain is maximal bout 18 months before the menarche, and that in boys at least this acceleration s closely followed by the attainment of a maturity score of 16 points for the innominate bone. Within each sex this acceleration is much greater for children who reach puberty relatively early.

(3) Although the major acceleration of maturation in the innominate bone is closely associated with the pubertal acceleration of stature, some acceleration of the maturity score can be seen as much as 5 years before the menarche.

(4) In girls the coefficient of correlation between the skeletal maturity score and stature is level from the 4th to the 8th year of life and then rises to a peak at about age 11. In the early years stature appears to correlate more closely with the maturity score for the femur than with that for the innominate bone, but later the position is reversed. In boys the correlation is initially lower than in girls, but rises to a higher peak in the 15th year.

(5) The acceleration in maturation of the innominate bone in each boy occurs within 6 months of the major acceleration in growth; in girls acceleration in skeletal maturity is less sharply associated with maximum height acceleration than in boys, but a close time relationship between the two exists in them also.

(6) Rapid maturation of the skeleton tends to be associated with less than average final height. *Within* each sex this is partially offset by an overlap between the factors determining the rates of growth and maturation, and also by the tendency for children with early puberty to undergo a more intensive growth acceleration. *Between* sexes, however, these "compensating" mechanisms do not apply: rapid femoral maturation of girls is not accompanied by more rapid growth, nor does their earlier puberty entail a greater growth spurt than boys.

(7) The possible hormonal factors responsible for these developmental patterns are discussed.

ACKNOWLEDGMENTS

It is again a pleasure to thank the late Dr. N. L. Hoerr and Dr. Alice Stewart for their encouragement and advice; and the Rockefeller Foundation, New York, and the Radcliffe Trust, Oxford, for financial aid in the form of personal grants to R.M.A.

LITERATURE CITED

Acheson, R. M. 1957 The Oxford Method of Assessing Skeletal Maturity, in Clinical Orthopaedics, *10:* 19–39.

Acheson, R. M., and D. Hewitt 1954 Oxford Child Health Survey. Stature and skeletal maturation in the pre-school child. Brit. J. Prev. Soc. Med., *8:* 59–65.

Acheson, R. M., and G. A. Zampa 1961 Skeletal maturation in ovarian dysgenesis and Turner's Syndrome. Lancet, *1:* 917–920.

Acland, J. D. 1958 The nature, determination and clinical importance of blood iodine: a review. J. Clin. Path., *11:* 195–205.

——— 1959 Personal communication.

Asling, C. W., M. E. Simpson, C. H. Li, and H. M. Evans 1954 The effects of chronic administration of thyroxin to hypophysectomized rats on their skeletal growth, maturation and response to growth hormone. Anat. Rec., *119:* 101–117.

Brown, P. S. 1958 Human urinary gonadotrophins. I. In relation to puberty. J. Endocrinol., *17:* 329–336.

Catchpole, H. R., and W. W. Greulich 1943 The excretion of gonadotrophic hormone by prepubertal and adolescent girls. J. Clin. Invest., *22:* 799–804.

Danowski, T. S., S. J. Huff, L. H. Erhard, M. Price, M. Brown, P. Wirth and S. S. Stevenson 1952 Protein-bound iodine levels in normal and in diabetic children. Amer. J. Dis. Child., *84:* 5–10.

De Pascale, A. 1956 La iodoprotide nell' infanzia. Lattante, *27:* 84–91.

Dorfman, R. I., W. W. Greulich and C. I. Solomon 1937 The excretion of androgenic and estrogenic substances in the urine of children. Endocrinology, *21:* 741–743.

Dupertuis, C. W., and N. B. Michael 1953 Comparison of growth in height and weight between ectomorphic and mesomorphic boys. Child Devel., *24:* 203–214.

Durham, J. R., R. E. Cooke, J. W. Lancaster and E. B. Man 1954 Serum butanol-extractable iodine values of children under 10 years of age. Amer. J. Dis. Child., *87:* 468–474.

Goldzieher, M. A. 1956 Treatment of excessive growth in the adolescent female. J. Clin. Endocrinol., *16:* 249–252.

Hain, A. M. 1947 The excretion of 17-ketosteroids and gonadotrophins in children: normal and abnormal cases. Arch. Dis. Childh., *22:* 152–158.

Hewitt, D., and R. M. Acheson 1961 Some aspects of skeletal development through adolescence. Pt. I. Variations in the rate and pattern of skeletal maturation at puberty. Amer. J. Phys. Anthrop., *19:* 321–332.

Hubble, D. 1957a Hormonal influence on growth. Brit. Med. J., *i:* 601–607.

——— 1957b Some principles of homeostasis. Lancet, *ii:* 301–305.

Johnston, J. A. 1941a Factors influencing retention of nitrogen and calcium in period of growth. IV. Effect of estrogen. Amer. J. Dis. Child., *62:* 708–715.

——— 1941b Factors influencing retention of nitrogen and calcium in period of growth. V. Further evidence of the anabolic effect of thyroid on calcium metabolism. Ibid., *62:* 1172–1182.

Johnston, J. A., and J. W. Maroney 1939a Factors affecting retention of nitrogen and calcium in period of growth. I. Effect of thyroid on nitrogen retention. Ibid., *58:* 965–982.

——— 1939b Factors affecting retention of nitrogen and calcium in period of growth. II. Effect of thyroid on calcium retention. Ibid., *58:* 1186–1198.

Kinsell, L. W., G. D. Michaels, C. H. Li and W. E. Larsen 1948 Studies in growth. I. Interrelationship between pituitary growth factor and growth promoting androgens in acromegaly and gigantism. J. Clin. Endocrinol., *8:* 1013–1036.

Low, W. 1952 Growth of Children. Aberdeen, Aberdeen Univ. Press.

Mellman, W. J., A. M. Bongiovanni and J. W. Hope 1959 The diagnostic usefulness of skeletal maturation in an endocrine clinic. Pediatrics, *23:* 530–544.

Miller, S., and H. L. Mason 1945 The excretion of 17-ketosteroids by diabetics. J. Clin. Endocrinol., *5:* 220–225.

Nathanson, I. T., L. E. Towne and J. C. 1939 The daily excretion of urinary an gens in normal children. Endocrinolgy, 335–338.

——— 1941 Normal excretion of sex mones in childhood. Ibid., *28:* 851–865.

Price, C. H. G. 1955 Osteogenic sarcoma: analysis of the age and sex incidence. Bri Cancer, *9:* 559–574.

——— 1958 Primary bone-forming tumors their relationship to skeletal growth. J. B Jt. Surg., *40B:* 574–593.

Pyle, S. I., and N. L. Hoerr 1955 Radiograp atlas of skeletal development of the k Charles C Thomas, Springfield, Ill.

Shuttleworth, F. K. 1937 Sexual maturat and the physical growth of girls age 6– Monogr. Soc. Res. Child Developm., *2:* No.

——— 1938 Sexual maturation and the sk tal growth of girls age 6–19. Ibid., *3:* No.

Simmons, K. 1944 The Brush Foundat study of child growth and development. P 2. Physical growth and development. Ibid., No. 1.

Sobel, E. H. 1956 The influence of testoster and cortisone on growth, in Adrenal funct in Infants and Children, ed. L. I. Gardner, N York, Grune and Stratton, pp. 137–156.

Sobel, E. H., C. S. Raymond, K. V. Quinn and B. Talbot 1956 The use of methyl-test terone to stimulate growth: relative influen on skeletal maturation and linear growth. Clin. Endocrinol., *16:* 241–248.

Tanner, J. M. 1955 Growth at Adolescen Oxford, Blackwell Scientific Publications.

Tanner, J. M., M. J. R. Healy, R. D. Lockh J. D. Mackenzie and R. H. Whitehouse 19 Aberdeen Growth Study. I. The prediction adult body measurements from measureme taken each year from birth to 5 years. Ar Dis. Childh., *31:* 372–381.

Thompson, W. O., and N. J. Heckel 1939 M sex hormone: clinical application. J. Am Med. Assn., *113:* 2124–2128.

Todd, T. W. 1937 Atlas of skeletal maturati (Part I, Hand). St. Louis, Mosby.

Werff ten Bosch, J. J. van der 1959 Norm en Abnormale Geslachtsrijping, Leiden Un Sers.

Study of the Size and Shape of Cross Sections f Hair from Four Races of Men[1]

DONALD G. VERNALL
Department of Anatomy, The University of Michigan, Ann Arbor, Michigan

The physical characters of hair have ten been given a leading position among e attributes used for the classification of uman races. Many of the descriptions of air features used in the past, however, ave been lacking in precision. Only re- ntly have investigators begun to apply ore precise measures to human hair char- ters.

The variability which occurs among the airs from a single person, and among per- ons known to belong to the same race, owever, presents a serious obstacle to the se for racial classification of even pre- sely measured characters. Considerable ncertainty exists about the amount of ariability among the hairs of a single per- on as compared to the variability among ersons, and about the variability among ersons within a racial group as compared the variability among racial groups.

This study supports and extends previ- us studies of hair types of human races. applies a set of measures to the treat- ent of variation in hair characters; and ubmits these measures to an analysis of ariance to determine the amount of varia- ion within and among races.

METHODS

Collection of sample

Hair samples were collected from 86 nales who were 20 to 30 years old as fol- ows: 20 Chinese who had been born on he Chinese mainland; 21 individuals who ad been born, or whose parents had been orn, in Great Britain, Germany, France, or olland; 26 Asiatic Indians who were born n India; and 19 Negroids of whom 9 were orn in Nigeria, 9 in the United States, and ne in Jamaica.

In no case was any individual excluded rom the sample on the basis of hair character, although no individual was included who acknowledged mixed ancestry.

Each hair sample was cut as close to the scalp as possible from the area overlying the external occipital protuberance.

Preparation of specimens

Hair samples were cleaned by soaking for 24 hours in each of 5 changes of 100 ml of carbon tetrachloride. The samples were blotted with paper towels and air-dried for several minutes after each immersion before being placed in the next jar of cleaning solution.

Parlodion was used to embed the hairs in preparation for sectioning. The sections, cut with the Hardy sectioning device (Steggerda, '40) and a Gillette microtome blade, were mounted on a slide with thin piccolyte. A glass coverslip of "O" thickness was applied, and subjected to light pressure to flatten the curled film of Parlodion. The slide was placed in a drying oven for a week.

Measurements

A research microscope equipped with a 2 mm N.A. 1.30 apochromatic objective and 15 × compensating eyepiece was used to measure the mounted cross section of hairs under a magnification of 1350 ×. The Köhler method (Shillaber, '44; 93–96) of illuminating the field was used. A micrometer disc served to measure the lengths of the hair axes to the nearest half quadrat of the micrometer disc. Each quadrat measured 8.2 microns (μ) on each side.

Measurements were made on a single cross section of each hair, about 0.5 cm from the proximal end. The first 30 cross sections of hair encountered in each mounted specimen were measured to avoid any bias in the selection of hairs. Preliminary statistical analysis indicated that a sample of this size would be adequate to measure the variability.

---

[1] This paper represents a condensation of a section of a dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in The University of Michigan.

The shape of hair in cross section is elliptical and varies from a nearly circular ellipse with major and minor axes approximately equal in length to a more flattened type with the major axis twice the length of the minor axis. Rare modifications impart a kidney, pear or triangular shape. An index, the quotient obtained by dividing the length of the minor axis by the length of the major, is used as a measure of shape. The area of a hair cross section is calculated from major and minor axes by assuming that the shape of all hairs approaches that of an ellipse, and by using the formula (pi $D_1 D_2/4$) for the area of an ellipse.

RESULTS

The measurements of each charac indicate that much variability occu among the hairs from each person, amo the persons within each race, and amo races (table 1). The measurements ha accordingly been subjected to an analy of variance (Snedecor, '46: 214–22 which reveals that the variability amo persons in each race is significantly grea than the within-person variability amo hairs (table 2).

Further analysis indicates that, for ea of the 4 traits measured, the variabil among the 4 races, here considered, is s nificantly greater than the variabil among the persons within each ra (table 2).

In an effort to determine which rac differ significantly from the other rac each group was compared separately w

TABLE 1

Racial means and their standard errors of length of major axis, length of minor axis, area and inc of hair cross sections

	Major axis	Minor axis	Area	Index minor axis / major axis
	μ	μ	μ^2	
Chinese	94.28 ± 3.05	76.79 ± 2.12	5816.9 ± 407.2	0.8264 ± 0.011
Western Europeans	81.94 ± 2.47	56.74 ± 1.33	3786.5 ± 185.9	0.7116 ± 0.014
Asiatic Indians	92.94 ± 1.93	66.49 ± 1.54	4993.5 ± 202.6	0.7292 ± 0.011
Negroids	98.23 ± 2.45	58.52 ± 1.87	4648.9 ± 255.8	0.5996 ± 0.010

TABLE 2

Results of analysis of variance of the measurements of hair sections

Tests	Degrees of freedom	F values required for significance levels of:		F values obtained			
		0.05	0.01	Length of major axis	Length of minor axis	Area	Index
Within races:							
Chinese	19/580	1.61	1.94	18.95[2]	19.51[2]	30.80[2]	10.31[2]
Western Europeans	20/609	1.59	1.91	12.45[2]	11.26[2]	13.47[2]	12.05[2]
Asiatic Indians	25/754	1.52	1.80	9.45[2]	16.72[2]	14.86[2]	8.70[2]
Negroids	18/551	1.63	1.97	13.64[2]	19.44[2]	23.14[2]	8.38[2]
Among all 4 races	3/82	2.72	4.03	7.77[2]	26.93[2]	9.45[2]	53.37[2]
Between races							
Chinese—W. Eur.	1/39	4.09	7.33	10.10[2]	65.87[2]	28.10[2]	21.07[2]
Chinese—As. Ind.	1/44	4.06	7.24	0.02	60.43[2]	3.76	35.22[2]
Chinese—Negroids	1/37	4.10	7.37	1.01	41.52[2]	6.07[1]	202.15[2]
W. Eur.—As. Ind.	1/45	4.06	7.22	12.87[2]	21.99[2]	18.64[2]	0.97
W. Eur.—Negroids	1/38	4.10	7.35	22.10[2]	0.62	7.71[2]	37.72[2]
As. Ind.—Negroids	1/43	4.06	7.26	2.95	54.00[2]	1.14	65.76[2]

[1] Shows significance in the 0.05–0.01 probability range.

[2] Shows significance beyond the 0.01 probability range.

ch of the other groups in regard to the rious traits.

Length of major axis

The mean length of major axis for the airs from any one person ranges from 3.49 ± 2.46 μ for a Western European 125.00 ± 4.30 for a Chinese. The vari- nces of the length of the major axes of the air sections from each person range from 2.092 for a Negro to 726.520 for an Asi- tic Indian.

So far as length of major axis is con- erned, Negroid hairs are on the average ne largest; Western European, the small- st; while Chinese and Asiatic Indian hairs re intermediate in size (table 1). The ifference between Western Europeans and ach of the three other groups is signifi- ant, although these other groups do not iffer significantly from each other in this espect.

Length of minor axis

The mean length of minor axis for the 0 hairs from any one person ranges from 3.05 ± 1.16 μ for a Western European o 100.18 ± 2.99 for a Chinese. The range f the within-person variances from 25.428 or a Negroid individual to 313.478 for an siatic Indian indicates further the vari- bility among individuals for this trait.

If length of minor axis is used as the riterion, the Chinese have on the average he largest hairs and Western Europeans he smallest (table 1). Asiatic Indians are n general intermediate between these two xtremes. The Western European and Negroid subjects are similar to each other and are the only pair which do not differ significantly in regard to length of minor axis.

Cross-sectional area

The person whose hairs have the small- est mean cross-sectional area is a Western European with a mean of 2017.4 ± 122.7 μ^2. The hair sections with the largest mean area are from a Chinese and meas- ure 10105.2 ± 535.0 μ^2. The within-person variances for area of hair sections range from 362,163 for a Negro to 8,585,186.5 for a Chinese.

Hairs from Chinese have the greatest mean area (table 1); those from Western Europeans, the smallest. The cross-sectional areas of Asiatic Indian and Negroid hairs are similar to each other, but intermediate between those of the Chinese and Western European hairs. The differences between the Western Europeans and the other three groups are significant. The Negroid subjects differ from the Chinese at the 0.05 level of significance. The Asiatic Indian sample, however, does not differ significantly from the Chinese nor from the Negroid samples.

Index of hair cross sections

The hair index provides another measure of the combined effect of the major and minor axes and is used as a reflection of the shape of the cross section of the hair.

The smallest index measured in this study is 0.50 which is the index of a hair with the shape of a flattened ellipse and with a major axis twice as great as the minor axis. The largest index measured is 1.00. In such hairs the shape of the cross sections closely approximates that of a circle. This range is in agreement with those reported by Danforth ('25) and Kneberg ('35).

The smallest mean obtained from the indices of the hairs from any single person, a Negroid subject, is 0.5370 ± 0.0078, and the largest within-person mean index is 0.9146 ± 0.0129 for a Chinese. The within-person variances for the index range from 0.0018 to 0.0221. Both of these individuals belong to the Negroid group.

As measured by the index (table 1), the Chinese hair sections are the most nearly circular in shape; the Negroid sections are the most flattened; and the Western European and Asiatic Indian hair sections are intermediate in shape. The latter two groups do not differ significantly from each other, but all other differences between races in regard to hair index are statistically significant.

DISCUSSION

The methods for obtaining, sectioning, and measuring the hairs were designed to secure samples suitable for statistical treatment. Sampling was restricted to subjects between the ages of 20 and 30 years in order to minimize the effect of age on hair character (Trotter, '30; Duggins and Trotter, '51). Between these ages, the amount of variation in hair character due to age is slight (Trotter and Duggins, '48). The possible variability in hair characters due to the difference in the sex of the subjects (Trotter and Dawson, '34; Steggerda and Seibert, '41) was avoided by measuring hair specimens from males only. Measurements were made on a single cross section taken from approximately the same area of each hair in an effort to minimize the variation that occurs in each hair throughout its length from base to tip (Kneberg, '35; Garn, '46).

The Chinese, Asiatic Indian, Western European, and Negroid individuals who supplied the hair samples for this study may not be a random sample of their respective populations, as most of the subjects were university students. Consequently, the racial differences here observed cannot be extended to the whole populations of these 4 races. Nevertheless, bias was avoided so far as possible in taking the hair samples and it is believed that they do represent adequately the individual and the series of individuals measured. Consequently, it is believed that the differences between the races shown by these measurements indicate the type of racial differences in hair characters which actually occur.

Chinese

Although the Chinese rank second in regard to length of major axis, they have on the average the largest hairs of the 4 groups in terms of length of minor axis and area of cross section. They differ significantly only from the Western Europeans so far as length of major axis is concerned, while in terms of length of minor axis they differ significantly from each of the other groups. In terms of cross-sectional area, they are, again, significantly different from Western Europeans, but differ from Negroids at only the 0.05 level and from Asiatic Indians not at all.

The shape of the cross sections of hairs of the Chinese is more nearly circular on the average than that of any of the other races. The mean index for the Chinese is 0.8264 ± 0.0117 and is significantly different from that for any other race. Woo
bury and Woodbury ('32) obtained indic
for North American Indian tribes that,
though smaller than that obtained here f
the Chinese, are larger than those obtain
in the present study for the Western Eur
pean, Asiatic Indian, or Negroid groups.

Western European

The Western Europeans have on t
average the smallest hairs in cross sectio
of the 4 races here considered (table 1
This holds true for length of major ax
length of minor axis, and, concomitantl
the area. The differences are significant
all cases but one, namely the difference
length of minor axes between Wester
European and Negroid samples.

The shape of the cross section of ha
from Western Europeans is on the avera
like that of hair from Asiatic Indians, ar
intermediate between that of Chinese ha
and that of Negroid hair. The Wester
Europeans do not differ significantly fro
the Asiatic Indians but are significant
different from each of the others at th
0.01 level of significance.

Asiatic Indians

The cross sections of hairs from Asiat
Indians are generally intermediate in si
relative to the other groups. They are si
nificantly larger than those of Wester
Europeans in all three measures of siz
They exceed the cross sections of Negro
hairs in length of minor axis (differenc
significant at the 0.01 level) and in are
(difference not significant) but are su
passed by those of Negroid hairs in lengt
of major axis (difference significant at th
0.01 level). Cross sections of hair fro
Asiatic Indians are out-ranked by thos
from Chinese in regard to all three mea
ures of size, although, except for diffe
ences in length of minor axis, these di
ferences are not significant.

Basu ('41) in a study of 50 adult mal
Noluas of Bengal reported a mean cros
sectional surface of 0.00315 mm² whic
differs considerably from the mean are
obtained in this study, 0.0049 mm². Suc
a difference, however, might be anticipate
since Basu's Noluas are a small isolate
subsample of the Asiatic Indians as
whole.

The shape of the cross sections of hair from Asiatic Indians does not differ significantly from that of Western Europeans (table 2). Both of these groups have hair which is intermediate in shape of cross section between those of the Chinese and Negroid groups, and these differences are significant. Basu ('41) obtained a mean index of 0.774 for hair samples from the Bengalese Noluas, a value intermediate between the mean index, 0.7292 ± 0.0112, obtained here for the Asiatic Indians, and 0.8263 ± 0.0117, the mean index obtained here for the Chinese.

Negroids

The cross sections of hairs from Negroid subjects have the longest major axes, on the average, of all the groups here considered, although they differ significantly only from Western European hair cross sections in regard to this characteristic. When the other measures of size are considered, it is found that the Negroid sample is outranked by the Chinese and Asiatic Indian groups but exceeds the Western European. Most of these differences are significant (table 2).

The elliptical shape of the cross sections of Negroid hairs is in general the most flattened of those of the 4 races, and consequently the average index for the Negroid sample is the smallest. Furthermore, the differences between the Negroid group and each of the other racial groups are significant at the 0.01 level, so that shape of cross section is apparently a more useful criterion for distinguishing Negroid hairs than is any single measurement of size. These results are in agreement with those reported by Steggerda and Seibert in '41.

SUMMARY

Measurements were made of cross sections of 30 hairs collected from the occipital region from each of 86 males, 20 to 30 years of age. Of this group, 19 are Negroid; 26 are Asiatic Indian; 21 are Western European; and 20 are Chinese.

Among the hairs from each person, variability is high for all the characters measured: length of the major and minor axes of the cross section, cross-sectional area, and cross-sectional shape.

Among those persons of each racial type, variability also is high for all of these measures. Highly significant F values were obtained from an analysis of the among-person and within-person variability within each of the 4 racial groups.

Among the races included in the study, variability, for each of the traits measured, is significantly greater than the variability among persons within each race. Racial differences consequently do exist within this sample for each attribute.

Chinese have, in general, the largest and most nearly round hairs of the 4 races measured in this study.

The Western Europeans included in this study have, on the average, the smallest hairs in cross section of the 4 groups.

The Asiatic Indian hair sections examined in this study are indistinguishable in shape from those of the Western Europeans. Both are intermediate between the most nearly circular Chinese hair sections and the Negroid hair sections, which were most flattened in shape. In size of cross section, hairs of Asiatic Indians were exceeded by those of the Chinese in all respects and by Negroid hairs so far as length of major axis is concerned.

The flattened elliptical shape of the Negroid hair sections is their most characteristic feature. In mean length of major axis, they are not significantly different from the Chinese nor from the Asiatic Indians. In the mean length of the minor axis, they are not significantly different from the Western Europeans. In mean area, they are not significantly different from the Asiatic Indians.

It is believed that the differences between the races shown by these measurements indicate the type of racial differences which actually occur in hair characters.

LITERATURE CITED

Basu, M. N. 1941 Study of the head-hair of the Noluas of Bengal. Univ. Calcutta Anthrop. Papers, *6:* 79–80.

Danforth, C. H. 1925 The hair. Nat. History, *26:* 1.

Duggins, O. H., and M. Trotter 1951 Changes in morphology of hair during childhood. Ann. N. Y. Acad. Sci., *15:* 569–575.

Garn, S. M. 1946 Hair structure related to hair form. Amer. Journ. Phys. Anthrop., *4:* 252, abs. no. 2.

Kneberg, M. 1935 Improved technique for hair examination. Ibid., *20:* 51–67.

Shillaber, C. P. 1944 Photomicrography in Theory and Practice. New York: John Wiley and Sons.

Snedecor, G. W. 1946 Statistical Methods Applied to Experiments in Agriculture and Biology, 4th ed. Ames: Iowa State College Press.

Steggerda, M. 1940 Cross sections of human hair from four racial groups. Journ. Hered., *31:* 474–476.

Steggerda, M., and H. C. Seibert 1941 Size and shape of head hair from six racial groups. Ibid., *32:* 315–318.

Trotter, M. 1930 The form, size, and color head hair in American whites. Amer. Jour Phys. Anthrop., *14:* 433–445.

Trotter, M., and H. Dawson 1934 The hair French Canadians. Ibid., *18:* 443–456.

Trotter, M., and O. H. Duggins 1948 A changes in head hair from birth to maturi I. Index and size of hair of children. Ibid., n *6:* 489–506.

Woodbury, G., and E. T. Woodbury 1932 D ferences between Certain of the North Am ican Indian Tribes as Shown by a Microscopic Study of Their Head Hair. Publ. State Hi Soc. Colorado, 37 pp.

omparative Spectrophotometric Absorption of the igments from Non-Red Human Hair[1]

B. L. HANNA [2]
University of Chicago, Chicago, Illinois and Medical College of Virginia, Richmond, Virginia

Gardner and MacAdams ('34) and Reed
52) have shown that although the mean
ectrophotometric reflectance curves of
d and non-red human hair differ in form,
e variation within color groups is so great
at individual hair samples may not be
liably classified with respect to color.
anna ('56) found that colorimetric meas-
rement of pigment concentration could
istinguish between light and dark non-red
uman hair, but again would not permit
iscrimination for individual hair samples.
hus all attempts to devise a quantitative
ethod for the classification of human hair
olor have ended in failure.

The present study examines the distri-
ution of spectrophotometric absorption
urves obtained for pigment solutions from
elected samples of non-red hair from the
uman population. Although it fails to
rovide an objective method for the dis-
rimination of non-red hair colors, the
tudy provides evidence suggesting that
otal pigment concentration may be a
ajor determinant of visible hair color and
onsequently a valid measure of color dif-
erence. Certain inconsistencies appear
mong the data which provide a basis for
peculations regarding the origin of hair
olor differences in man.

MATERIALS AND METHODS

Hair samples of approximately 100 to
00 mg each were cut from the crown of
he head of each of 254 individuals (127
nrelated twin pairs) attending Chicago
igh schools during the school year 1942–
943.[3] Before cutting, the hair of each
ndividual was classified with respect to
olor by Dr. R. M. Snodgrasse, using the
aarfarbentafel of *Fischer* ('07). The hair
amples were stored in the dark in sealed
nvelopes. When the present analysis was started, 60 of the hair samples were picked at random and without knowledge of the color grade previously assigned, were again classified according to Fischer's scale by the present investigator. Because no systematic color changes were found it was concluded that there had been little or no alteration of the hair color during storage. The grades assigned at the time of collection have been assumed correct and are the ones referred to throughout this report. Additional hair samples were obtained by the same sampling method from students at the University of Chicago from 1949 to 1951 and were assigned grades by the present investigator.

Spectrophotometric analysis has been made of the hair of 40 pairs of same-sex dizygous twins, 39 pairs of monozygous twins and 24 unrelated individuals. In the present study the hair of only one of each pair of monozygous twins is included in order to avoid bias to the within-grade variation. Both members of a dizygous pair are included only if the hair of the two members is not of the same color grade. Hair samples which could not be definitely classified into one of the Fischer grades are not included. The 94 hair samples reported here are from 34 unrelated monozygous twins, 39 dizygous twins and 21 non-twins. Fischer's Haarfarbentafel is a visual standard consisting of 30 samples of artificial hair arranged in series according to increasing color intensities. The gray-black series ranges from very light gray (grade No. 21) to intense black (nos. 27–30); no shade has a yellowish or reddish component. The yellow-brown series extends from off-white (grade No. 20) to dark brown-black (no. 4) with many colors having a reddish component. The hair samples reported here are distributed among the Fischer grades as follows:

---

[1] The major portion of these data were collected during the tenure of a National Cancer Institute Fellowship at the University of Chicago. Additional experimental work and analysis at the Medical College of Virginia was supported in part by grants from the A. D. Williams Research Fund.

[2] Present address: National Institutes of Health, U. S. Public Health Service, Department of Health, Education and Welfare, Bethesda, Maryland.

[3] Hair samples were collected in conjunction with a study of mental traits in twins (T. G. Thurstone, L. L. Thurstone and H. H. Strandskov).

Yellow-brown series

Grade	Color (Fischer)	Number
4	Dark brown-black	20
5	Brown-black	17
6	Nut brown	3
7	Brown	5
8	Light brown	6
9	Golden brown	1
10	Light golden brown	2

Gray-black series

Grade	Color (Fischer)	Number
23	Wood-ash gray	2
24	Dark ash gray	1
25	Mouse gray	16
26	Dark gray	8
27	Black	10
28	Black (curled)	3

The methods of extracting hair pigments and of obtaining spectrophotometric readings are given in detail elsewhere (Hanna, '53). Briefly the method is as follows. Individual hair samples were washed in a solution of neutral detergent, were dried, and were then defatted with cold distilled ether for 8 hours in an Underwriter's type extraction apparatus. Following drying, duplicate 50 mg samples were weighed and were hydrolyzed with 25 ml of 0.2 N potassium hydroxide by boiling under reflux for about two hours. The solutions, containing hydrolized hair keratin and pigments, were returned to volume and were read immediately against standard solutions of hydrolized pigment-free nail keratin. The preparation and characteristics of the keratin standards have been given earlier. Hair pigments have been shown repeatedly to follow Beer's Law in the visible light range. Readings were made with a Coleman Junior spectrophotometer, Model 6-A, using matched cuvettes. Three independent readings of each solution w made at wave length 400 mμ and two dependent readings at every 50 mμ fr 450 to 700 mμ, giving a total of 7 me optical density estimates in the visi light band. The present report is based the optical densities at only 5 of these wa lengths; 450, 500, 550, 600, and 650 n Eight samples (4 individual hair samp in duplicate) and a keratin standard so tion were prepared and read at one tin The samples were randomized before beginning of the study and the solutic were read at random in order that subj tive bias might be reduced to a minimu

RESULTS

The mean optical densities of the so tions of pigment from hair of 13 colors 5 wave lengths in the visible light band a given in table 1. Grades 9 and 24 ea contain only a single individual and given at the bottom of the table. The sults obtained for these two color grad will not be considered further. Grades and 27, which contain hair samples fr both Caucasians and Negroes, are s divided in the table. Dark hair colors a pear to have a greater total pigment c centration than do lighter hair colors, indicated by their greater optical densit at all wave lengths. The variation in o cal densities is, in general, greater amo the dark than among the light colors. T Negro hair samples appear to have grea pigment concentration and greater var tion at all wave lengths than do Caucasi samples of the same visual color gra (nos. 4 and 4N, 27 and 27N). These servations confirm previously reported sults based on colorimetric examination hair pigments at a wave length of 400 (Hanna, '56).

The variances estimating variation reading samples (σ_r^2), variation resulti from errors in sampling and in the prepa tion of pigment solution (σ_s^2) and variati among individuals in the sample (σ_i^2) a given in table 2 for each of the 5 wa lengths. The 4th and 5th columns of ta 2 give estimates of the percentage of the tal variation at each wave length which the result of all errors (column 4) and t percentage of the total error variati which is the result of reading errors (c

TABLE 1

Mean optical densities, standard deviations and standard errors of the mean optical densities of solutions of pigment from hair of various color classes (Fischer, '07) at 5 wave lengths of visible light. The tabulated values give the distributions of the means of two sample optical densities from each of N individuals in each color group.

olor rade	N	Wave length in mμ 450 Mean and SE	450 SD	500 Mean and SE	500 SD	550 Mean and SE	550 SD	600 Mean and SE	600 SD	650 Mean and SE	650 SD
4	16	0.282 ±0.017	0.068	0.209 ±0.013	0.053	0.161 ±0.012	0.046	0.126 ±0.010	0.039	0.097 ±0.008	0.033
4N	4	0.388 ±0.095	0.189	0.289 ±0.065	0.130	0.213 ±0.043	0.086	0.160 ±0.029	0.058	0.120 ±0.019	0.038
5	17	0.206 ±0.015	0.064	0.155 ±0.013	0.053	0.118 ±0.011	0.044	0.092 ±0.009	0.036	0.071 ±0.007	0.030
6	3	0.252 ±0.001	0.002	0.174 ±0.001	0.001	0.124 ±0.001	0.001	0.089 ±0.001	0.001	0.073	0.000
7	5	0.157 ±0.023	0.051	0.114 ±0.018	0.041	0.083 ±0.014	0.032	0.064 ±0.012	0.026	0.048 ±0.009	0.021
8	6	0.173 ±0.011	0.026	0.119 ±0.009	0.021	0.087 ±0.008	0.020	0.063 ±0.006	0.016	0.047 ±0.005	0.012
0	2	0.134 ±0.001	0.001	0.091 ±0.001	0.001	0.066	0.000	0.051		0.037	
23	2	0.061	0.001	0.047	0.000	0.036		0.030		0.020	
25	16	0.149 ±0.015	0.061	0.109 ±0.012	0.047	0.083 ±0.010	0.039	0.065 ±0.008	0.032	0.049 ±0.006	0.025
26	8	0.110 ±0.010	0.027	0.075 ±0.008	0.021	0.054 ±0.006	0.018	0.041 ±0.005	0.013	0.030 ±0.004	0.010
27	5	0.384 ±0.022	0.049	0.316 ±0.022	0.049	0.261 ±0.022	0.050	0.215 ±0.021	0.046	0.175 ±0.019	0.042
27N	5	0.484 ±0.048	0.108	0.389 ±0.049	0.109	0.310 ±0.046	0.103	0.251 ±0.042	0.095	0.200 ±0.036	0.081
28	3	0.507 ±0.097	0.258	0.386 ±0.086	0.229	0.290 ±0.073	0.193	0.221 ±0.060	0.160	0.168 ±0.048	0.128
9	1	0.171		0.123		0.089		0.066		0.047	
24	1	0.049		0.037		0.026		0.019		0.014	

TABLE 2

Variation resulting from colorimetry (σ_r^2), sample measuring error (σ_s^2) and among individual variation (σ_i^2) estimated from observations on 94 hair samples at each of 5 wave lengths

Wave length (mμ)	Variance (× 10^{-8}) σ_r^2	σ_s^2	σ_i^2	% variation due to all errors	% of error due to reading
450	243	8645	404931	2.15	2.73
500	244	8373	263352	3.17	2.83
550	230	7929	173925	4.72	2.67
600	152	8076	111215	6.89	1.85
650	206	8390	72671	10.07	2.53

Mean $\sigma_r^2 = 215 \pm 117$ (× 10^{-8}).
Mean $\sigma_s^2 = 8283 \pm 123$ (× 10^{-8}).
Mean $\sigma_i^2 = 205219 \pm 59426$ (× 10^{-8}).

umn 5). The mean reading error is 2.5% and is constant at all wave lengths. Analysis of variance of the differences among triplicate readings at 7 wave lengths taken on 16 different hair samples indicate that the error between wave lengths is less than the error between successive readings of the same sample at one wave length [$F_{(96,112)} < 1.0$; $P > 0.05$]. Although the error variation does not differ significantly at different

TABLE 3

Regressions of the logarithms of optical density on wave length in mμ of various hair color grades. $\bar{x}$ is the mean wave length (= 550 mμ); $\bar{y}$ the mean logarithm of optical density at $x = \bar{x}$; $SE_{\bar{y}}$ the standard error of $\bar{y}$; b the coefficient estimating the slope of the regression line; and SE_b the standard error of the regression coefficient.

Color grade	N[1]	$\bar{y}$		$SE_{\bar{y}}$	b		SE_b
4	80	0.1965	±	0.0143	−0.00236	±	0.00020
4N	20	0.3036	±	0.0380	−0.00243	±	0.00017
5	85	0.0488	±	0.0185	−0.00239	±	0.00026
6	15	0.1079	±	0.0079	−0.00280	±	0.00011
7	25	−0.0985	±	0.0354	−0.00264	±	0.00050
8	30	−0.0646	±	0.0191	−0.00287	±	0.00027
10	10	−0.1649	±	0.0077	−0.00275	±	0.00011
23	10	−0.4438	±	0.0128	−0.00238	±	0.00018
25	80	−0.1115	±	0.0204	−0.00246	±	0.00029
26	40	−0.2709	±	0.0221	−0.00286	±	0.00031
27	25	0.4092	±	0.0201	−0.00174	±	0.00028
27N	25	0.4675	±	0.0382	−0.00209	±	0.00017
28	15	0.4115	±	0.0777	−0.00263	±	0.00110

[1] The number of observations is equal to the number of individuals in a color grade times the number of wave lengths at which readings were obtained.

wave lengths, the variation among individuals decreases to such a degree at the red end of the spectrum that the relative amount of total error increases from 2.2% at 450 mμ to over 10% at 650 mμ.

The logarithm of mean optical density (× 10) was taken as the dependent variable for the estimation of regression coefficients. This transformation was made in order that the relationship between this variable and wave length might be linear as reported by Spiegel-Adolph ('37) and *Daniel* ('38). The mean logarithm of optical density (y) and the estimated slope of the regression line (b) together with their standard errors are given for each of the color groups in table 3. All of the regression coefficients differ from zero at the 0.01 level except that of color grade 28, which differs at the 0.05 level.

To determine whether the slope of the regression line is independent of the pigment concentration of a solution, the correlation between the mean logarithms of optical density and slope was calculated from two different types of data. A correlation of + 0.46 was obtained between mean optical density and regression line slope for the 13 color grades studied. In addition, serial dilutions were made of pigment solutions from 4 dark hair samples (Grade 27) and spectrophotometric readings were obtained. The mean logarithms of optical density and the slopes of regression lines of these 4 samples at each of
dilutions are given in table 4. The corre
tion between optical density and slope
−0.39 for these differing concentrations
pigment from the same hair sampl
Neither of these correlation coefficier
deviates significantly from zero at the 0.
confidence level. There is no evidence fr
these small samples that the slope of t
regression line is related to the concent
tion of hair pigments in the solution.

The logarithms of optical density of co
classes 27 and 8 plotted against wa
length are shown in figure 1. The regr
sion lines have been reduced to a comm
origin at λ = 450 mμ to facilitate compa
son. This figure illustrates the range wi
in which all of the hair color regressi
lines occur, since grades 27 and 8 ha

TABLE 4

Logarithms of mean optical densities ($\bar{y}$) a
regression coefficients (b) of serial dilutions
of pigment solutions from dark hair
samples. The unit concentration was
obtained by the hydrolysis of
50 mg of fat-free hair in
25 ml 0.2 N KOH

Concentration	y	b
1	0.8348	−0.003
1/2	0.5624	−0.002
1/4	0.2661	−0.002
1/8	−0.0374	−0.003
1/16	−0.2909	−0.002

$r_{\bar{y}b} = -0.3864$ $P > 0.05$.

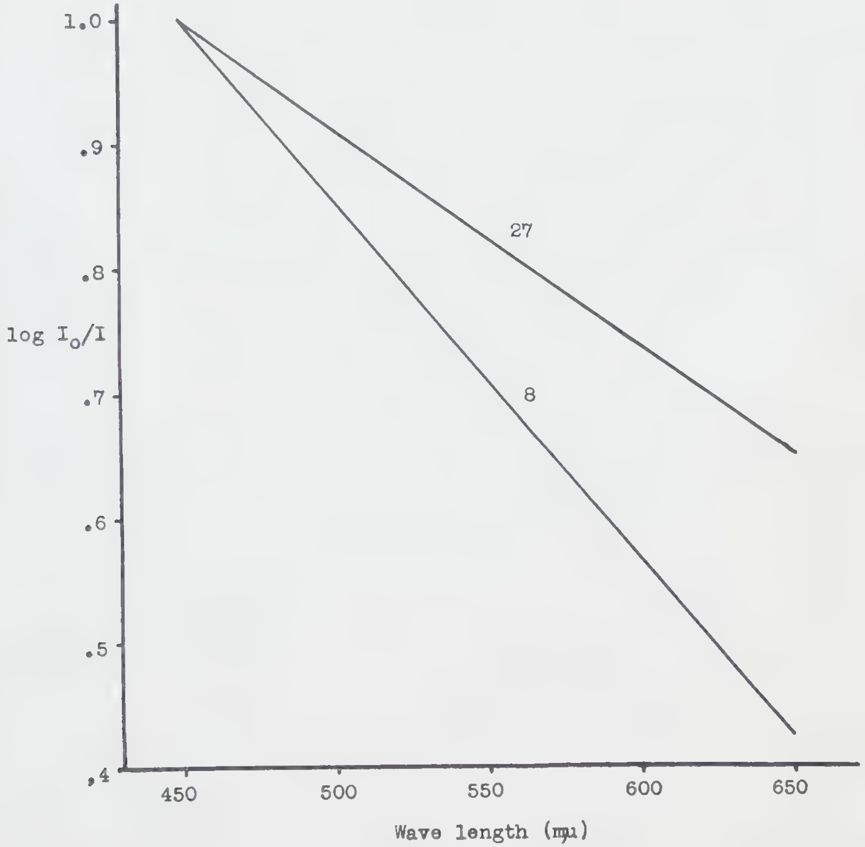


Fig. 1 The regression of log optical density on wave length for pigment solutions of hair of Fischer grades 27 and 8.

respectively the smallest and greatest slopes. In order to better illustrate the slope differences, the color class having the least slope (27) was assigned zero slope, and each of the other color classes was then given a slope proportional to this. These proportional slopes, unrelated to pigment concentrations in the various color grades, are illustrated in figure 2.

To determine whether the observed slopes of the regression lines of various color grades differ significantly, each regression coefficient (*b*) has been compared with every other one. A valid comparison may be made only if the variances of the within-grade coefficients are independent estimates of the variation within the population from which the various color classes are drawn. The homogeneity of the variances was tested by the method of Bartlett ('37), omitting the variances of grades 28 and 7, which appear to be grossly out of line with the other estimated variances. Even when these are omitted a χ^2 value of 37.71 is obtained. With *10* degrees of freedom, this value indicates a probability of less than 0.01 that the remaining color classes are drawn from the same population. The variation of individual regression coefficients were therefore compared with each other using the F test for the comparison of variances. The variance (σ_b^2) of grade 28 was found to be significantly greater at the 0.01 level than that of any other grade. The probabilities of similarity between variances for the other color grades are given in table 5. It should be noted that previous results (Hanna, '56) indicate that the error variation in the color classes may not be of the same magnitude. The variation in regression line slope in the color classes appears to be

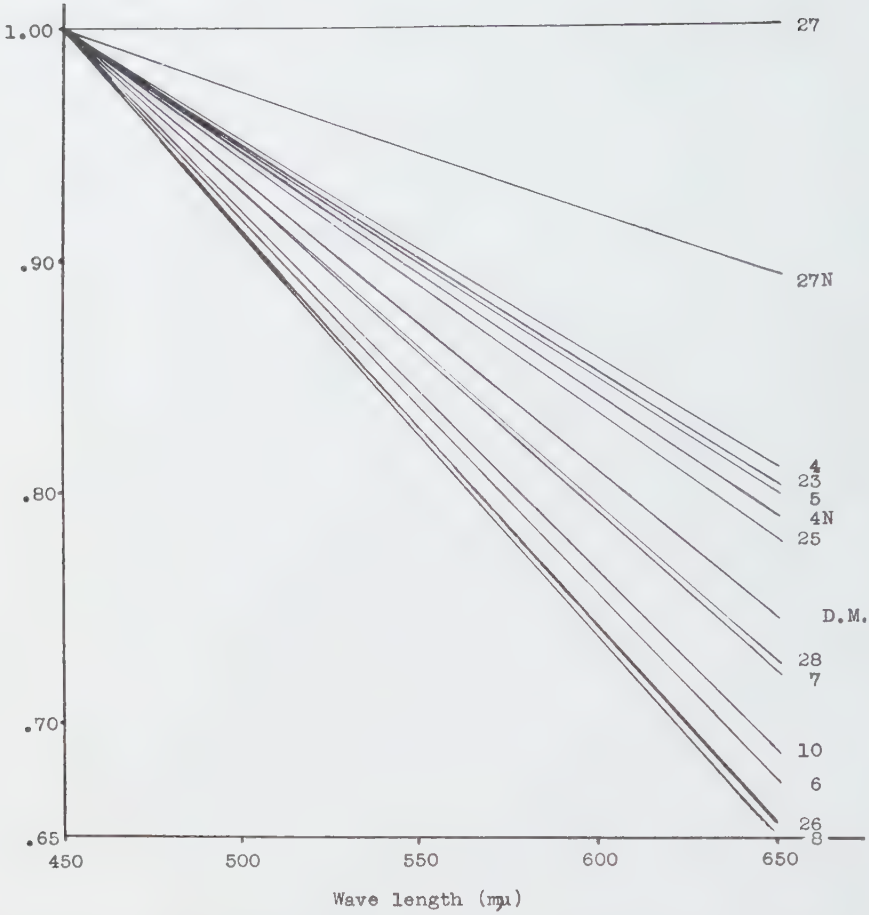


Fig. 2 The relative slopes of regression lines for hair of different colors, plotted with the darkest hair (no. 27) assigned zero slope.

TABLE 5

Probabilities that the variation about the regression lines (σ_b^2) *of various hair color grades are of the same magnitude. The probabilities are given only for those comparisons for which the variation in the two color groups differ significantly. Based upon the F test* $(F = \sigma_{b1}^2/\sigma_{b2}^2)$; *color grades arranged in order of increasing pigment concentration.*

Color grade having greater mean square	Color grade having lesser mean square									
	26	10	25	8	5	6	4	4N	27	27N
26						0.01	0.01	0.01		0.01
25						0.05	0.01	0.01		0.01
7	0.01	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.05	0.01
8						0.05	0.05	0.05		0.05
5						0.05	0.05	0.05		0.05
27						0.05	0.05	0.05		0.05

unrelated to mean optical density ($r = +0.04$). In grades 4 and 27 the variation among Negroes is less than among Caucasians, although not significantly so for grade 4.

The slopes of the regression lines (*b* values) were compared with the *t* test. The probabilities of similarity are given in table 6. The decrease among individual variation at longer wave lengths (noted above) results in part from greater error of the spectrophotometer when measuring low optical densities. Although this error is greater for hair colors having low pigment concentration, it is seen (table 4) that these are the colors having greater rather than lesser slope. The truncating effect of this machine error thus biases these data in favor of the null hypothesis. The estimated probabilities given in table 6 may be greater than would be obtained in the absence of this error. Two of the nine significant differences occur between groups having significantly differing variation (between grade 27 and grades 4N and 6). It may be said with confidence only that the regression coefficient of grade 27 differs from those of grades 8, 10 and 26 and that of grade 27 N from those of the same three grades plus grade 6. It appears that only the grades with greatest and least slope may be differentiated by this method.

The observed differences in slope may be attributed to one or more of the following found among hair of different color groups: (1) differences in the chemical nature of the pigments; (2) differences in the mean size of the pigment granules; (3) differences in the nature of the conjugant proteins or (4) differences in the nature of the residual hair proteins in the test suspensions. The latter two of these possible differences could not be demonstrated. Following spectrophotometric analysis the melanin granules from 8 light brown and 8 dark hair samples were precipitated by the addition of 6 N HCl and were removed by centrifugation. Analysis of the supernatents revealed no systematic differences in absorption curves. The results are summarized in table 7. The precipitated granules were redissolved by heating with 0.2 N

TABLE 6

Probabilities that the coefficients of regression of the logarithms of optical density on wave length of various hair color grades are of the same magnitude. Probabilities are given only for those comparisons for which the coefficients differ significantly. Grades arranged in order of increasing regression line.

Color grade	27N	4	23	5	4N	25	28	7	10	6	26	8
27					0.05				0.01	0.01	0.05	0.01
27N									0.01	0.01	0.05	0.05

TABLE 7

Analysis of optical densities of supernatants from pigment solutions from light brown and black hair

		O.D. at λ =				
	N =	450	500	550	600	650
Light brown	8	0.0458	0.0196	0.0103	0.0066	0.0053
Black	8	0.0436	0.0170	0.0086	0.0053	0.0051

Variaton	d.f.	Sum of squares	Mean square ($\times 10^3$)
Within samples among wave lengths	64	0.0175640	0.274438
Among samples within colors	14	0.0005598	0.039986
Among colors	1	0.0000450	0.045000
Total	79	0.0181688	

$F_{(1,14)} = 0.889, P > 0.05.$

KOH and absorption curves obtained. No changes in the absorption curves of the pigments were seen at this time or following a second precipitation.

The logarithm of optical density expected at $\lambda = 450$ mμ has been calculated from the regression equation for each color grade. The values are compared with the mean logarithms of the observed optical densities in table 8. The observed and expected values do not differ greatly. To determine the relative importance of concentration and regression slope in determining the expected values, the logarithmic values expected if (1) only the type of pigment present effects the estimate ($\bar{y}$ constant for all color classes) and (2) only the pigment concentration effects the estimate (b constant for all color grades) were calculated for each grade. Their values are given in columns C and D of table 8. The relative variation is reduced considerably more when concentration is held constant, suggesting that differences in the natures of pigments may play a relatively minor role in determining the observed optical density at a given wave length. Colorimetric readings in the visible light range therefore give good estimates of total pigment concentration.

DISCUSSION

Since the percentage of total variati resulting from error is independent of tot pigment concentration (Hanna, '56), t greater within-grade variation in conce tration observed for visibly dark colo must result either from (1) greater heter geneity with respect to the residual hydr lyzed material which is found in solutio of dark hair or (2) greater heterogenei of the pigment granules themselves. B cause the experimental evidence fails suggest a difference in the structural mat rial of light and dark hair (table 7), it concluded that the pigment of dark hair more variable.

Although only the visibly darkest an lightest hair colors may be differentiate on the basis of regression lines, colors the yellow-brown series have, with one e ception, slopes greater than any color the gray-black series except no. 26 (tab 3). The one exception includes those ye low-brown colors considered by Fischer have a black component (nos. 4 and 5 Although no significant correlation b tween slope and concentration can be den onstrated among the 13 color grades, th slopes of both the browns and the black appear generally to decrease with increa

TABLE 8

Logarithms of optical density at 450 mμ calculated from the regression coefficients of individual hair color grades when both concentration and regression slope are allowed to vary (column B), only regression slopes allowed to vary (column C) and only concentration allowed to vary (column D).

Color grade	Mean of logarithm of observed optical density	Expected logarithm of optical density		
		$\bar{y}$ and b variable (B)	$\bar{y}$ constant (C)	b constant (D)
4	0.43811	0.43211	0.29644	0.44541
4N	0.54824	0.54629	0.30354	0.55249
5	0.29263	0.28741	0.29944	0.29771
6	0.40053	0.38750	0.34044	0.35680
7	0.17310	0.16518	0.32454	0.15038
8	0.23278	0.22220	0.34764	0.18430
10	0.12646	0.10999	0.33574	0.08399
23	0.21254	−0.20617	0.29844	−0.19487
25	0.14091	0.13427	0.30664	0.13737
26	0.03141	0.01495	0.34664	−0.02145
27	0.58152	0.58292	0.23454	0.65812
27N	0.67536	0.67614	0.26944	0.71644
28	0.67456	0.67433	0.32364	0.66043
Mean	0.31562	0.30978	0.30978	0.30978
S.D.	0.26755	0.26950	0.01023	0.28513

ing concentration. The slopes of gray hair appear, conversely, to increase with increase in concentration. The machine error of the spectrophotometer is such that the observed optical densities of light colored pigments are relatively higher than are those of the dark pigments at long wave lengths. This may explain, in part, the increase in observed slope with concentration in the gray hair samples, but would indicate that the true slopes of the light brown samples may be greater than observed. No evidence is adduced to support the hypothesis that the conjugant proteins in light and dark hair pigment granules are of importance in effecting differences in regression line slope.

Barnicot et al. ('55) have found pigment granule size and morphology to be distinctly different in human hair of different colors. In general, dark pigment granules are larger and more ovoid in shape than are brown or reddish granules. These large granules should, in suspension, lead to a greater amount of Tyndall scattering in the spectrophotometer. All other things being equal, we should then expect the pigments from dark hair to have a measurable optical density at the blue end of the spectrum considerably higher than light hair pigments, and consequently to have greater regression line slopes. Since the dark pigments do not have greater slope, it is probable that pigment granule morphology is not the most important factor affecting the slope.

If the true difference in regression line slope between dark and light brown hair pigments is as great or greater than observed and cannot be explained by differences in pigment granule size, in conjugated proteins or in the structural material of the hair, it must be concluded that some quantitative difference in the pigments exists. In an earlier publication (Hanna, '56) it was demonstrated that the distribution of pigment concentrations in non-red hair could be adequately explained by postulating two pigments, independent of each other in occurrence. It was suggested that 4 or 5 different shades of yellow-red pigmentation might be distinguished in hair of the yellow-brown series. Butenandt et al. ('56, '57) and Glassman ('57) have demonstrated that the production of melanins and pheuoxazono pigments may not be independent in insects. The present data fail to provide evidence concerning the dependence or independence of dark and red pigment production in man.

Although visibly black hair (no. 27) was found to have a slope differing significantly from that of light brown hair colors, this difference appears to have little value as an aid in the objective classification of color. Gardner and MacAdams ('34) observed that the spectrophotometric reflectance curves of black and brown hair differ, but noted that within either group it is not possible to distinguish among gradations of color. Differences in pigment concentration appear to be the major factor determining the observed differences in optical density in these data, the nature of the regression curve having relatively little effect on colorimetric values obtained at low wave lengths. Colorimetric comparisons of total pigment concentrations thus may serve as valid indicators of hair color differences. Unfortunately, the reliability of subjective visual distinction of hair colors among different grades varies considerably (Lea, '54; Hanna, '56). The magnitude of the error in classification of some colors is such that the distributions of colorimetric readings for pigments may overlap to a considerable extent. It is therefore not possible to establish by either colorimetric or spectrophotometric methods a reliable objective scale for the discrimination of non-red hair colors.

SUMMARY

Spectrophotometric absorption curves of pigment solutions from 94 non-red human hair samples of 13 color grades have been obtained. The regression of the logarithms of optical density or wave length in the visible spectrum and the variation of the regression coefficient for each color grade was compared with those of other color grades.

The regressions of pigments from hair of dark colors on wave length are less than those of pigments from light hair. The regression appears to be unrelated to mean optical density (pigment concentration). The differences in slope of the regression line between light and dark hair pigments appear to be unrelated to differences in

(a) the nature of proteins conjugated with these pigments in the pigment granules, (b) the nature of the residual hydrolyzed proteins found in the pigment solutions and (c) pigment granule morphology. It is concluded that a quantitative difference exists between the pigments from gray-black and brown hair.

Differences in pigment concentration are shown to be more important indicators of hair color difference than are regression coefficients. It is not possible to establish an objective scale for the discrimination of non-red hair color.

LITERATURE CITED

Barnicot, N. A., M. S. C. Birbeck and F. W. Cuckow 1955 The electron microscopy of human hair pigments. Ann. Human Genet., *19:* 231–249.

Bartlett, M. S. 1937 Some examples of statistical methods of research in agriculture and applied biology. Supplement to the J. Roy. Stat. Soc., *4:* 137–170.

Butenandt, A., E. Biekert and B. Linzen 1956 Über Ommochrome VII. Mitteilung Modellversuche zur Bildung des Xanthommatins *in vivo.* Zeit. f. Physiol. Chemie., *305:* 284–289.

Butenandt, A., E. Biekert and G. Newert 1957 Über Ommochrome X. Modellversuche zur Konstitution der Ommochrome: 5-dibenz (b. f) a pinchinonimine als Reaktionsproducte der acetyl-phenoxazone mit Alkali und als Oxyd tionsproduckte des 2-amino-3-hydroxy-acetoph nons. Ann. Chemie., *603:* 200–216.

Daniel, J. 1938 Studies of multiple allelomo phic series in the house mouse. III. A spectr photometric study of mouse melanin. J. Ge etics, *36:* 139–143.

Fischer, E. 1907 Die Bestimmung der mensc lichen Haarfarben. Korrespondenz. Blat Deutsch Gesell. f. Anthropologie, Ethnologie Urgeschichte, *38:* 141–147.

Gardner, B. B., and D. L. MacAdams 19 Colorimetric analysis of hair color. Am. Phys. Anthrop., *19:* 187–201.

Glassman, E. 1957 Tyrosinase-produced qui ones and the disappearance of kynurenine larval extracts of *Drosophila melanogaste* Arch. Biochem. and Biophys., *67:* 74–89.

Hanna, B. L. 1953 On the relative importanc of genetic and environmental factors in th determination of human hair pigment conce tration. Am. J. Human Genet., *5:* 293–321.

——— 1956 Colorimetric estimation of the pi ment concentration of hair of various colo grades. Am. J. Phys. Anthrop., *14:* 153–174.

Lea, A. J. 1954 Estimation of the amount pigment present in human hair. Ann. Huma Genet., *19:* 97–99.

Reed, T. E. 1952 Red hair colour as a genetica character. Ann. Eug., *17:* 115–139.

Spiegel-Adolph, M. 1937 Studies on melanin I. Photosynthetic melanins. Bio. Chem. J., *3* 1303–1310.

Association Between Alternate Sequences of Hand-Wrist Ossification

STANLEY M. GARN, CHRISTABEL G. ROHMANN AND
DONALD K. WALLACE[1]
Fels Research Institute, Yellow Springs, Ohio

In a previous study of hand-wrist ossification, we demonstrated the existence of marked individual variations in ossification sequence (Garn and Rohmann, '60). Whereas the literature had asserted constancy of sequence and uniformity of order for the postnatal nuclei of the hand and wrist, individual longitudinal analyses revealed great variability instead.

Moreover, for many pairs of ossification centers having similar median ages at appearance, "alternate" sequences were in fact the rule. A given pair of centers would frequently be characterized by a more common (or A-B) sequence and a less common (or B-A) order of ossification.

Such alternate ossification sequences involving early-appearing and the late-appearing pairs alike, raised the question of independence or association for alternate sequences. Obviously a lack of association between alternate sequences of ossification would suggest the role of chance events, while a marked tendency toward association between pairs of alternate sequences would implicate common factors.

We have, therefore, investigated the extent to which alternate hand-wrist ossification sequences are associated in the course of osseous development.

METHODS AND MATERIALS

In setting up the present study, attention was paid to centers of ossification having similar median ages of ossification, and with alternate sequences as documented by individual analyses. Throughout, three criteria of selection were utilized. First, sequences were chosen to cover the entire range of appearance of centers from the early carpals and distal epiphysis of the radius to the late-appearing multangulars. Second, preference was given to those alternate sequences where the more common and less common orders were more nearly equal, in order to facilitate exact tests of association. Third, sequences involving a common center were excluded from the comparisons, since variations in the order of appearance of that center would necessarily affect both sets of alternate sequences involved.

Of the many possible alternate sequences of hand-wrist ossification suggested by table 3 in Garn and Rohmann ('60), a total of 18 met all three criteria. Population frequencies were calculated for these 18 alternate sequences using the "index" series of 154 boys and girls exclusive of like-sexed siblings (Garn and Rohmann, '59, '60). Combined-sex tabulations were then employed, as in table 1, since sex-differences were not significant at the $p = .05$ confidence level.

Associations between alternate sequences of hand-wrist ossification were determined except for pairs of alternate sequences having an ossification center in common. The technique of analysis was the Chi-squared test for fourfold tables, correcting for small samples in any single cell (cf. Siegel, '56; and fig. 1). The approach was thus identical to the familiar test of association between dichotomous attributes, except that 278 Chi-squared tests were run in all.

In this work tedious hand sorting was minimized by using edge-punched Royal-McBee "Keysort" cards to indicate the A-B or B-A order for each of the 18 alternate sequences, and the "Keysorter" was employed to sort the cards into the appropriate 4 categories for each test after exclusion of uninformative "bunched" centers.

---

[1] Present address: Western Reserve University School of Medicine.

TABLE 1

Alternate sequences in hand-wrist ossification[1]

Sequence no.[2]	More common sequence	No.	%	Less common sequence	No.	%	Tot
1	Dist. Radius–Prox. III	66	67	Prox. III–Dist. Radius	33	33	99
2	Prox. IV–Dist. I	48	60	Dist. I–Prox. IV	32	40	80
3	Prox. V–Met. IV	45	73	Met. IV–Prox. V	17	27	62
4	Prox. V–Mid. III	55	67	Mid. III–Prox. V	27	33	82
5	Mid. IV–Mid. III	12	57	Mid. III–Mid. IV	9	43	21
6	Mid. II–Met. V	47	60	Met. V–Mid. II	38	40	85
7	Mid. II–Dist. IV	58	74	Dist. IV–Mid. II	20	26	78
8	Dist. IV–Triquet.	64	55	Triquet.–Dist. IV	53	45	117
9	Triquet.–Met. I	59	51	Met. I–Triquet.	56	49	115
10	Dist. III–Met. I	59	68	Met. I–Dist. III	28	32	87
11	Dist. III–Prox. I	86	84	Prox. I–Dist. III	16	16	102
12	Prox. I–Dist. II	63	72	Dist. II–Prox. I	25	28	88
13	Dist. II–Dist. V	27	58	Dist. V–Dist. II	21	42	48
14	Dist. V–Mid. V	48	58	Mid. V–Dist. V	35	42	83
15	Mid. V–Lunate	82	68	Lunate–Mid. V	39	32	121
16	Lunate–Navic.	122	95	Navic.–Lunate	6	5	128
17	Lesser Mult.–Navic.	57	51	Navic.–Lesser Mult.	54	49	111
18	Lesser Mult.–Greater Mult.	54	52	Greater Mult.–Lesser Mult.	49	48	103

[1] Excluding cases where centers were "bunched" in time of appearance (cf. Garn and Rohmann ’60, p. 223).

[2] Arranged according to median order of appearance.

FINDINGS

As shown in table 2, where associations significant at $p = .05$ and $p = .01$ are enumerated, the number of associations between alternate sequences of ossification greatly exceeded expectancy. Of the 278 comparisons, 44 were significant at the 5% level and 24 of these were significant at the 1% level or better. Clearly, the tendency to be A-B or B-A in a particular alternate sequence was associated with similar tendencies throughout osseous development.

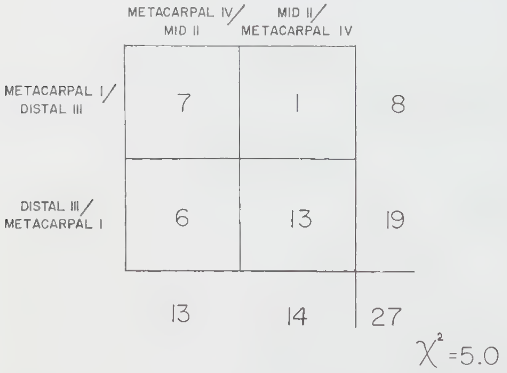


Fig. 1 Example of Chi-squared test involving the Metacarpal IV-Mid. II: Metacarpal I-Distal III alternate sequences. Since small cell values were frequent, the use of Finney's *Tables of Critical Values of D* and the Fisher Exact Probability Test eliminated much tedious computation (cf. Siegel, ’56, pp. 256–270).

Since the Chi-squared tests involved varying sample sizes, according to th number of "bunched" centers for a particular pairing, it was important to estimate the effects of sample size in under or over-estimating the total number o significant associations. Since the correlation between sample size and the number of significant associations was effectively zero ($r = 0.004$), there was reason to believe that the total of 16% of significant associations closely approximated the true proportion.

The significance data were further grouped according to anatomical criteria since a previous study has shown considerable autonomy (in time of appearance) for the carpal bones (Garn and Rohmann ’59). Similar results were apparent in the present study as shown in table 3. Out of 93 comparisons involving carpal centers, 10 (see table 3) were significant at p = .05 or better. In contrast, 26% of associations involving metacarpals, and 19% of associations involving digital centers were significant at the same level of probability. Since the measures of association were effectively independent, the inference is that alternate sequences involving digital and metacarpal centers have determinants

TABLE 2

Association between alternate sequences of hand-wrist ossification

	Alternate sequences	No. sequences compared[2]	Significant associations	
			$\chi^2 > 3.84$	$\chi^2 > 6.63$
1	Dist. Radius–Prox. III/Prox. III–Dist. Radius[1]	17	1	0
2	Prox. IV–Dist. I/Dist.I–Prox. IV	17	3	1
3	Prox. V–Met. IV/Met. IV–Prox. V	16[2]	4	2
4	Mid. III–Prox. V/Prox. V–Mid. III	15[2]	4	3
5	Mid. IV–Mid. III/Mid. III–Mid. IV	16	0	0
6	Mid. II–Met. V/Met. V–Mid. II	16	6	5
7	Mid. II–Dist. IV/Dist. IV–Mid. II	15	2	1
8	Dist. IV–Triquet./Triquet.–Dist. IV	15	4	3
9	Triquet.–Met. I/Met. I–Triquet.	15	1	0
0	Dist. III–Met. I/Met. I–Dist. III	15	5	3
1	Dist. III–Prox. I/Prox. I–Dist. III	15	0	0
2	Prox. I–Dist. II/Dist. II–Prox. I	15	5	3
3	Dist. II–Dist. V/Dist. V–Dist. II	15	0	0
4	Dist. V–Mid. V/Mid. V–Dist. V	15	5	1
5	Mid. V–Lunate/Lunate–Mid. V	15	2	1
6	Lunate–Navic./Navic.–Lunate	15	0	0
7	Lesser Mult.–Navic./Navic.–Lesser Mult.	15	1	1
8	Lesser Mult.–Greater Mult./Greater Mult.–Lesser Mult.	16	1	0
	Total	278	44[3]	24[3]

[1] More common/less common sequence as in table 1.
[2] Excluding pairs of sequences involving a common center.
[3] Chance expectancy 14 and 3 respectively.

TABLE 3

Associations between alternate sequences arranged according to anatomical areas

Associations involving	No. of associations	No. significant[1]	Per cent significant
Carpals	91	9	10
Metacarpals	62	16	26
Digits	217	42	19

[1] At $p = 0.05$ or better.

in common, whereas carpal centers exhibit greater autonomy.

In short, associations between "alternate" sequences of hand-wrist ossification are about 5 times as common as chance alone would dictate, presumably suggesting determinants in common.

DISCUSSION

The findings in this particular study are nearly self-explanatory, minimizing the need for extensive discussion. Clearly, alternate sequences of hand-wrist ossification are not totally independent events, though a common determinant hardly explains all of them. Moreover, alternate sequences appearing early in hand-wrist ossification are unquestionably associated with sequences that appear late thus excluding purely temporal (and transient) events.

The mere existence of such alternate sequences further dispells the notion of a fixed order of ossification. Besides the various sequences of carpal ossification previously described by us, table 1 of this study confirms variations in the sequence of digital and metacarpal ossification. Clearly, such variations are neither rare nor unimportant, nor can they be fully explained on the basis of temporary, transient delays (Greulich in Boell, '54).

Within the limits of the sample under consideration, it is clear that possession of the A-B or B-A sequences for one pair of centers is associated with particular alternatives for many other pairs of centers. As previously mentioned, this generalization particularly applies to metacarpal and digital centers of ossification. The inference is that relatively few determinants, genetic or otherwise, may account for intra-individual variability in hand-wrist ossification order. The extent of genetic involvement is now being investigated in extensive parent-child, sibling-sibling and co-twin comparisons.

SUMMARY

1. Alternate sequences in hand-wrist ossification, involving a more common (A-B) sequence and a less common (B-A) sequence were investigated for 18 such sequences in 154 children.

2. In a total of 278 comparisons using these 18 alternate sequences, 44 were significant at p = .05 or better.

3. Nineteen per cent of associations involving digital centers, 26% involving metacarpal centers and only 10% involving carpal centers attained the indicated level of significance.

4. It was suggested that relatively few determinants could account for a large portion of inter-child variability in hand-wrist ossification sequence.

ACKNOWLEDGMENT

The authors wish to thank Dr. and Mrs. John Lacey for their statistical suggestions and Lois A. Conklin for help in the man script preparation.

Financial support from research gra A-3816 of the National Institutes of Heal is herein acknowledged for the data ana ysis.

LITERATURE CITED

Garn, S. M., and C. G Rohmann 1959 Cor munalities of the ossification centers of tl hand and wrist. Am. J. Phys. Anthrop., *1* 319–323.

——— 1960 Variability in the order of ossi cation of the bony centers of the hand ar wrist. Ibid., *18:* 219–230.

Greulich, W. W. 1954 The relationship skeletal status to the physical growth and d velopment of children. In: Dynamics Growth Processes, E. J. Boell, ed. Princetc University Press, Princeton, chap. 10.

Siegel, S. 1956 Non-parametric Statistics f the Behavioral Sciences. McGraw-Hill Boc Company, Inc., New York.

Complete Epiphyseal Union of the Hand

STANLEY M. GARN, CHRISTABEL G. ROHMANN
AND BENJAMIN APFELBAUM
Fels Research Institute, Yellow Springs, Ohio

Although there is voluminous literature on the osseous development of the hand, the bulk of the tabular data pertains to the first 6 years of life. During this time period the majority of the digital, metacarpal and carpal centers appear, variations in sequence and timing are for the most part evident, and numerous anomalies of development in the post-natal ossification centers make their certain appearance (O'Rahilly, '53, '57).

In contrast, exact data on the completion of the hand (particularly with reference to the digital and metacarpal epiphyses) are scanty indeed. In the study of epiphyseal union the samples tend to be small in general (Stevenson, '24), the source of material is frequently unspecified (cf. Flecker, '42) and for the most part the values on American, Czech, Hindu and Egyptian children are grossly disparate (cf. Krogman, '41, pp. 558–576). We are inclined to agree, therefore, with Noback ('54) who takes a dim view of the samples involved, the accuracy of the data, and their usefulness at the present time.

Ideally, one would like information on the timing of epiphyseal union of the digital and metacarpal epiphyses with some indication of the degree of pattern regularity. Equally desirable would be information concerning the suitability of the hand as an indicator of osseous completion, and of completion of statural growth. Under these circumstances it would be possible to evaluate the utility of the hand as a measure of developmental progress during adolescence, and particularly for predicting long-bone growth and final stature.

It is the purpose of this paper, then, to report on the timing of union and the order of union of the 19 epiphyses of the hand. The analyses further include the relationship between complete hand union and such maturational measures as menarche and the time of complete tibial union. Finally, data are given on statural changes subsequent to complete hand union in order to determine the extent to which completion of the hand reflects the cessation of general growth.

METHODS AND MATERIALS

The present investigation is based upon serial longitudinal postero-anterior hand and lower leg radiographs, menarcheal data and incremental data on 107 white, Ohio-born participants in the Fels Longitudinal Program. Except for two sets of male triplets, separately studied, subjects were restricted to those who had achieved complete hand union, and like-sexed siblings were excluded from the tabulations (Garn and Rohmann, '59, '60, '61).

Although several stages of epiphyseal union in the hand were at first distinguished, following in part Moss and Noback ('58) and Noback et al. ('60), an exact comparison of metacarpal and digital union proved impractical. Moreover, histological validation of "intermediate" stages of epiphyseal union was unobtainable. Accordingly, therefore, data analysis was limited to complete union as indicated by the disappearance of the radiolucent line between diaphysis and epiphysis.[1] High internal correlations ($r > 0.95$) and good correlations with both menarche and age of tibial union ($r = 0.9$ and 0.7) confirmed the reliability and supported the validity of the maturational measure selected for investigation.

---

[1] For digital segments and the 5 metacarpals obliteration of the radiolucent line marks extension of bone completely across the epiphyseal plate. The radio-opaque line that follows complete union in the digital segments and the first metacarpal is variable in persistence, particularly on the first metacarpal where it may be radiographically visible for several decades.

Besides menarcheal data for 50 girls, taken from the longitudinal files, individual age-increments for stature were computed. Successive yearly increments were grouped for periods of one year, two years, three years and 4 years subsequent to complete hand union, in order to determine the extent to which overall growth continues after digital and metacarpal completion.

In providing tabular material on completion of individual centers, percentiles were necessarily employed because of the skewness of all maturational data. Correlations in turn were based on T-scores normalized by McCall's method (cf. Garn and Shamir, '58, Lacey, '56).

Finally, sequences of digital and metacarpal union were ascertained first on a grouped basis, using median values, and then on an individual basis as described by Garn and Rohmann ('60). Particular attention was paid to "fields" of union, and these were validated against the individual records.

FINDINGS

As shown in table 1, where sex-specific percentiles for the age at union are given, girls are uniformly ahead of boys in all 19 epiphyseal centers of the hand, as characterized by the general formula y 0.87 x. While the two sexes are comp rable in degree of skewness, girls are a solutely more variable than boys, thoug the F value (for pooled data) of 2.1 fai to attain significance at the $p = 0.5$ co fidence level (Guilford, '50).

With a uniform 13% temporal lead girls over boys, computing elapsed tin from birth, complete hand union th compares very closely with the 12% se difference in hand ossification in gener (cf. Garn, Lewis, Koski and Polachec '58). However, sexual dimorphism in th hand is obviously smaller than the 19 sex difference in knee ossification, or th rather large (26%) difference in the tin of appearance of postnatal ossificatio centers.

Taking the sex-specific median valu for age at union of individual digital ar metacarpal centers, and arranging them b anatomical groupings, the sequence dista proximal-middle-metacarpal emerges f both boys and girls, as shown by the fo lowing medians:

Segment	Age–Boys	Age–Girls
Distal	15.9	13.6
Proximal	16.2	14.3
Middle	16.4	14.4
Metacarpal	16.4	14.6

TABLE 1

Age percentiles for complete union of metacarpal and digital epiphyses

Center		Boys				Girls				Sex Diff. (k)[1]
		N	5	50	95	N	5	50	95	
Metacarpal	5	51	15.1	16.5	17.9	55	12.4	15.0	17.2	0.91
	4	51	15.1	16.4	17.9	54	12.3	14.6	16.8	0.88
	3	51	15.0	16.4	18.0	55	12.2	14.7	16.9	0.90
	2	51	15.0	16.4	18.0	55	12.2	14.6	16.9	0.89
	1	51	14.6	16.3	17.9	55	11.7	14.1	16.6	0.88
Proximal	5	51	14.3	16.2	17.9	57	11.8	14.2	16.2	0.87
	4	51	14.6	16.2	17.9	55	11.3	14.2	16.4	0.88
	3	51	14.4	16.3	17.8	55	11.8	14.3	16.4	0.87
	2	51	14.5	16.3	17.9	55	11.8	14.2	16.3	0.88
	1	51	14.7	16.3	17.9	54	12.1	14.4	16.5	0.87
Middle	5	51	15.1	16.4	17.9	55	11.8	14.3	16.6	0.89
	4	51	15.1	16.4	17.0	54	11.9	14.5	16.7	0.87
	3	50	15.1	16.4	17.9	53	12.1	14.5	16.6	0.88
	2	51	15.0	16.4	17.9	54	12.1	14.4	16.5	0.85
Distal	5	51	14.2	16.0	17.8	57	11.8	13.6	15.7	0.85
	4	51	14.2	16.0	17.7	56	11.9	13.6	15.8	0.85
	3	51	14.2	16.0	17.6	56	11.6	13.6	15.7	0.85
	2	51	14.2	16.0	17.8	57	11.7	13.6	15.7	0.86
	1	51	14.1	15.7	17.6	57	11.4	13.5	15.7	0.86
"Spread"[2]			1.0	0.8	0.4		1.0	1.5	1.5	0.06

[1] $y = kx$.

[2] Range lowest to highest values.

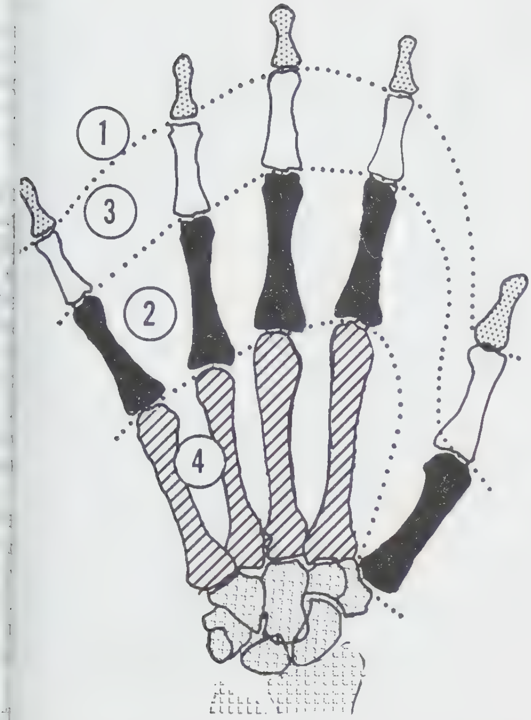


Fig. 1 "Fields" of complete hand union as determined in the present study. In the sequence (1) distal, (2) proximal, (3) middle and (4) metacarpal, metacarpal I behaves like a proximal segment.

The first metacarpal, however, is allied to the proximal segments in time of union for both sexes, as is evident in table 1. A better sequence, therefore, is distal, proximal (including metacarpal I), middle and metacarpal (excluding metacarpal I). It may also be noted that anatomically the first metacarpal more nearly resembles the proximals to which it is obviously allied in time of union (see fig. 1).

The distal-proximal-middle-metacarpal sequence, pictured in the first figure, is further justified by individual sequential analyses. In all but a very few cases, distal epiphyses or the entire distal segment precede the others in the order of epiphyseal union (table 2). In fact, the distal epiphyses of the first digit tends to head the progression of epiphyseal union. There are, however, marked individual variations in the relative position held by the first and third metacarpal, and the 4th and 5th proximal epiphyses (table 2 and fig. 2). Nevertheless, the massed data sequences, notably ineffective in regard to the order of appearance of centers (Garn and Rohmann, '60) suggest more effectively the order of complete union.

While it might be thought that the time of union of metacarpal and digital epiphyses would be related to the time of appearance of these same centers, no evidence is forthcoming from the present study. Using the rank-order correlation (rho) values for the order of appearance versus the order of union are −0.09 for girls and 0.02 for boys. Correlations involving the *timing* of appearance and the time of union are similarly low. Clearly, ossification during the first 6 years and union during the 'teens are strikingly unrelated: "maturation" of bone is not a unitary phenomenon.

A logical further question is the extent to which hand union relates to epiphyseal union elsewhere in the body, and to other steroid-mediated changes. This can be ascertained, first with respect to the union

TABLE 2

Order of union in digital and metacarpal epiphyses as observed in 61 cases

Initial order	26 Boys		35 Girls	
	No.	Per cent	No.	Per cent
Distal I	6	23.1	4	11.4
Distal III	1	3.8	—	—
Distal I and III	2	7.6	—	—
Distal V	3	11.5	1	2.8
Distal I and V	–	—	1	2.8
Distal segment	6	23.1	18	51.4
Distal segment and metacarpal I	3	11.5	3	8.6
Distal segment and metacarpal III	–	—	1	2.8
Distal segment and proximal IV	1	3.8	1	2.8
Distal segment and proximal V	4	15.3	5	14.2
Proximal IV and metacarpal I	–	—	1	2.8

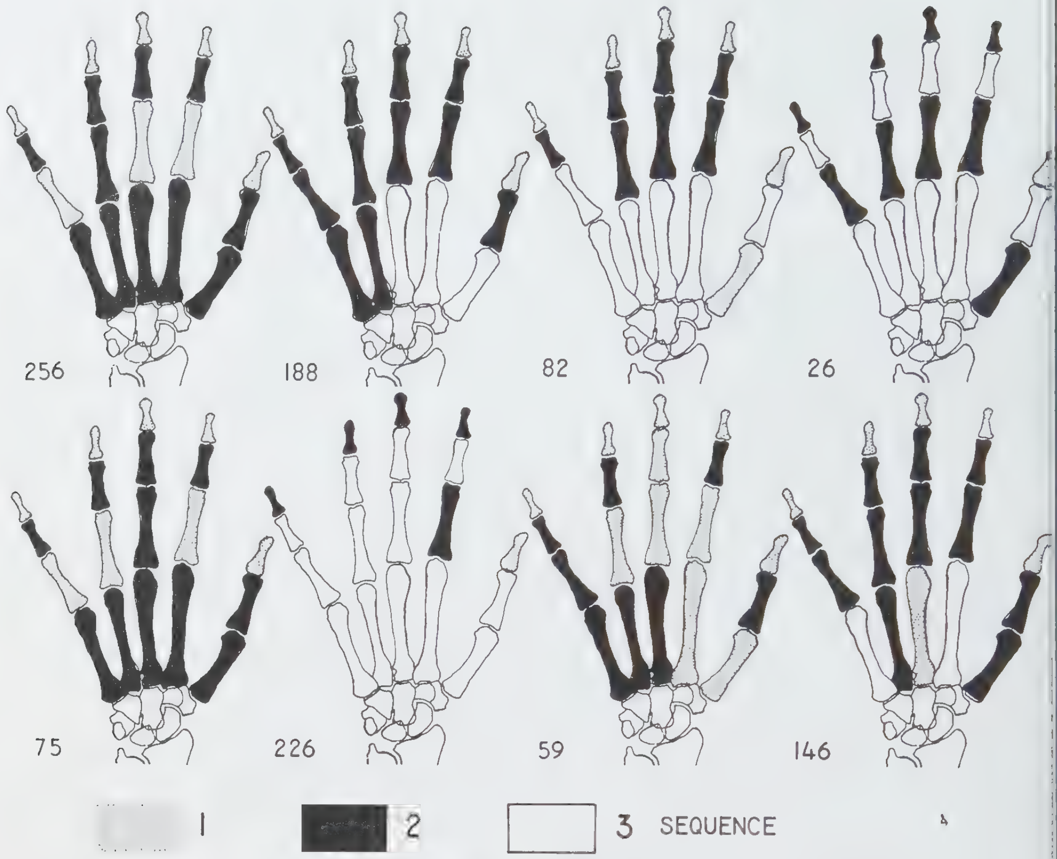


Fig. 2 Individual variations in complete union of digital and metacarpal epiphyses. Despite variations in completion of the first and fourth metacarpals and the first and fifth distal segments, the o der given in figure 1 holds on an individual basis (cf. table 2).

of the proximal tibial epiphysis in both sexes, and with respect to menarche in the female. Taking menarche first, hand union proves to be a highly correlated event ($r = 0.91$) in 50 cases. Complete tibial union is also reasonably covariant, with r values of 0.78 for 49 girls and 0.72 for 43 boys. However, complete hand union does not hold a uniform temporal relationship to union of the proximal tibial epiphysis. Combining both sexes, in the absence of statistically significant differences, it appears that complete hand union may either precede or succeed complete tibial union, as pictured in figure 3. There are tibia-first children and tibia-last children. Union of the hand is no reliable guide to when tibial union will occur.

Since the hand has in some studies bee used as an indication of statural maturity or a guide in predicting final size, it is o interest to analyze stature increments a yearly intervals subsequent to complet hand union. This arrangement show quite clearly that stature increments sub sequent to hand union vary considerabl from child to child. As shown in figure 4 some children grow but little once th hand is complete. In fact there is a sug gestion that stature may in some instance be complete *before* the hand is full united. In other cases, however, increase of as much as 5 cm may be expected i the 4 years following complete han union. Particularly for girls, the hand i an inadequate guide in predicting fina stature.

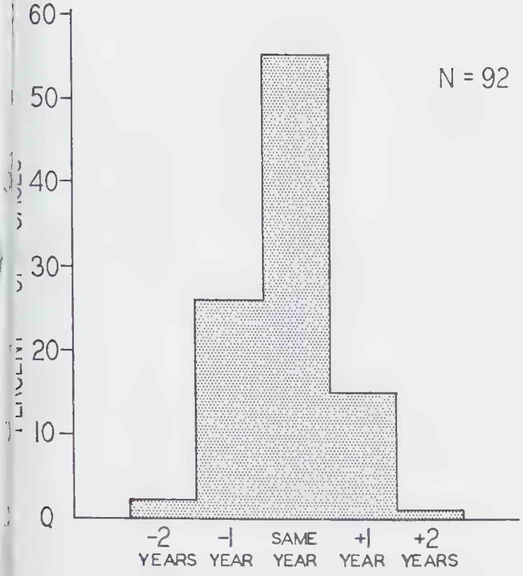


Fig. 3 Relative timing of (proximal) tibial nion and complete hand union. Since tibial nion may either precede hand union or succeed by as much as two years, the hand is obviously mited as a reference standard for long-bone rowth.

Some children are fast-uniters, closing ll 19 epiphyses within the span of a single year. Other children are slow uniters, spreading union over a 3 or 4 year period. Attempts to relate the rapidity of union o age at maturity, or to the rate of linear growth are so far not successful. Seemingly, therefore, the rate of hand union is not a function of the age at maturity or the magnitude of the growth spurt. Logically, the fast hand uniters ought to be rapid maturers, but we have been unable to confirm this hypothesis.

While it cannot be shown that the abruptness of digital and metacarpal completion relates to the tempo of maturation, there is evidence that the time of union, and the pattern of epiphyseal closure are in part gene-determined. With one set of male monozygotic triplets, the "K" triplets (45, 46 and 47), the T-score profile patterns are virtually identical. With another male set, the "B" triplets, comprising a monozygotic pair and a dizygote (305, 306 and 307) the profile patterns are highly congruous for the monozygotic pair but markedly dissimilar for the dizygote number 307. The suggestion, then, is that genes bear on the timing and patterning of complete hand union, given reasonable uniformity in nutritional background.

In short, while complete hand union is obviously related to the tempo of maturation, there are marked regional autonomies. The hand has its own and characteristic degree of sexual dimorphism. Within the hand there are individual, presumably gene-mediated differences in sequence and timing. The hand is an imperfect guide as to the timing of lower limb completion, and is even less effective as a measure of statural completion.

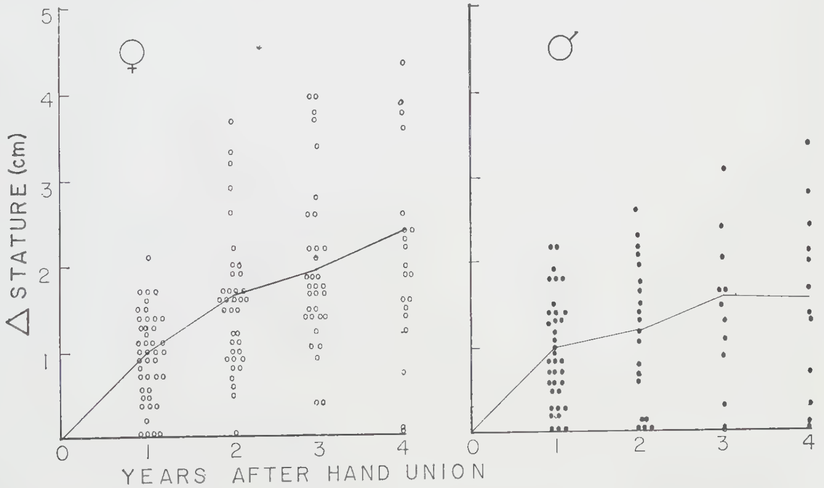


Fig. 4 Stature increments subsequent to complete hand union. Since stature increase over the 4 years following hand union may be less than 1 cm, or as much as 5 cm, hand union cannot be taken as a good indication of final size.

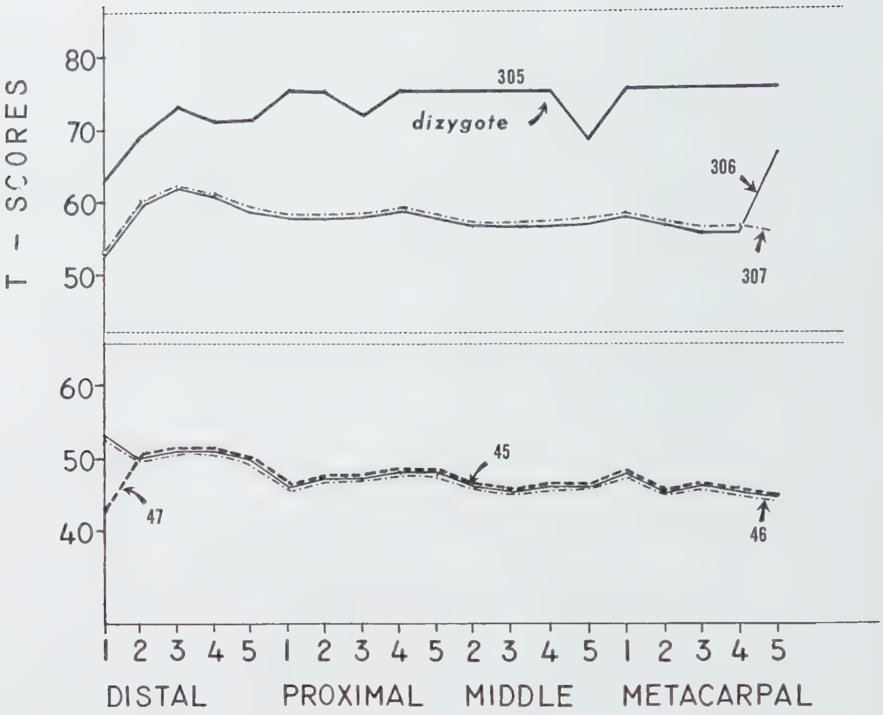


Fig. 5 T-score profile patterns of complete hand union for two sets of like-sexed male triplets. In both sets the patterns for the monozygotes are virtually identical while the dizygote diverges in both pattern and level (cf. Garn, '55).

DISCUSSION

Reviewing the preceding findings on the age at union of the epiphyses of the digits and metacarpals, first attention may be directed to sex differences. In hand union, as in maturation in general, girls are advanced over boys. However, the extent of sexual dimorphism in complete hand union (averaging 13% for all 19 epiphyses concerned) is rather small compared to the 19% sex difference in the knee, and the 26% difference in appearance of ossification centers. Noting also the extremely small (4–5%) sex difference in tooth formation and eruption, it would appear that there are considerable regional and anatomical differences in the magnitude of maturational dimorphism with areas more remote from the pelvic center less markedly divergent in the time of completion.

A further item of interest is the sequence or order of complete hand union. Based on the median values, the sequence would appear to be distal-proximal-middle-metacarpal in both sexes. More caref analysis allies the first metacarpal wi the proximal segment as a whole, analysis confirmed by individual sequenc as well. Thus, as in the study of co munalities of hand-wrist ossification (Ga and Rohmann, '59) time-linked phenon ena do assort themselves along anatomic lines. With over 600 radiographs involv in the present study and after the analys summarized in table 2, we do not feel necessary to reconcile our distal-proxima middle-metacarpal "fields" with those pr viously deduced by Noback et al. ('60

The regional nature of osseous develo ment is further exemplified by comparin hand union with tibial union. Though t two are highly correlated, and the media ages are extremely similar, it is a fa that union of the proximal tibial epiphys may antecede hand union by as much two years, or succeed it by an equ amount. Thus, for a substantial propo tion of the adolescent population, the b havior of the hand is no sure guide ng-bone maturation. As in the appearance of ossification centers (Garn and ohmann, '61), the hand is to some extent an island unto itself, grossly related to, but also autonomous of bony maturation sewhere in the body.

The limitations of the hand as an indication of growth in general are equally clear in statural increments. A few adolescents, perhaps 5–10% of the population, are substantially complete in growth by he time the metacarpals and digits have completed their union. Other children have as much as 5 centimeters to grow in the ensuing 4 years. Grossly, the hand does provide a quick appraisal of osseous status, but for such problems as long bone growth or the prediction of final stature, more information is needed than the hand alone supplies.

A further difficulty is raised by individual differences in the rate of complete epiphyseal union of the hand. Some children are rapid uniters, fusing all 19 digital and metacarpal epiphyses in the space of a single year. Others are slow uniters, taking as much as 4 years to complete the same sequence of union. Logically, the rapid uniters should be rapid, even early maturers. With equal logic the slow uniters should be slow, presumably late maturers. But the two groups unfortunately are not demonstrably different by our analyses so far, and it is therefore impossible to say that what is logical is demonstrably true.

These studies on union of epiphyseal centers, like the investigations on appearance of the same centers, clearly bear on the use of bone-age assessments. The fact that appearance of centers and union of centers are virtually uncorrelated, either on a sequential basis or a timing basis, mitigates against any assumption of neatly channelwise developmental progress. Large, but still inexplicable differences in the rate of completion make it unwise to assume that a large proportion of completely united centers is — within individuals — indicative of greater or more rapid maturity.

Finally, attention must be paid to the similarity of monozygotes in timing and sequence of complete hand union, and the concomitant dissimilarity of dizygotes from the same triplet sets. Such data, resembling Buschke ('34), do not of course introduce intra-triplet nutritional extremes. Nevertheless the evidence does suggest that within nutritionally-determined limits, the order of union and the timing of union of the digital and metacarpal epiphyses is to a large extent gene-controlled.

SUMMARY

1. The age at union of digital and metacarpal epiphyses was investigated in serial hand radiographs of 107 white Ohio-born children.

2. Girls were advanced over boys by 13% in complete hand union, a value considerably smaller than the extent of sexual dimorphism in the knee, or in the appearance of ossification centers in general.

3. Both from median data, and in individual sequential analyses, the order of complete hand union could be given as distal-proximal-middle-metacarpal with metacarpal I behaving like a proximal segment.

4. No relationship was found between the order of appearance of the 19 digital and metacarpal epiphyses and the sequence of union, or between the time of appearance of these centers and the time of union.

5. Although complete hand union and union of the proximal tibial epiphysis were moderately correlated (combined sex $r = 0.75$) tibial union preceded hand union by as much as two years in some cases and succeeded it by an equal amount in others.

6. Stature increments subsequent to complete hand union were highly variable, amounting to as little as 1 cm or as much as 5 cm in the 4 years following hand union.

7. From monozygotic and dizygotic twin and triplet pairings, there was evidence for genic control of both timing and sequence of complete hand union.

8. Evidence for the regional autonomy of metacarpal and digital union places practical limits on the hand as an indication of long-bone completion and as a guide in predicting final stature.

ACKNOWLEDGMENTS

We are grateful to Joan Adams Haskell for permission to use data on tibial union, to Batsheva Bonné for preparation of the illustrations and technical assistance, and to Lois Conklin for assistance in manuscript preparation. We are indebted to Dr. Frederic N. Silverman for many helpful suggestions in the course of the study.

Financial support, in part, from Research Grant A-3816 from the National Institutes of Health is herein acknowledged.

LITERATURE CITED

Buschke, F. 1934 Roentgenologische Skelettstudien am menschlichen Zwillingen und Mehrlingen. Leipzig, Georg Thieme.

Flecker, M. B. 1942 Time of appearance and fusion of ossification centers as observed by roentgenographic methods. Am. J. Roentgenol. and Rad. Therapy, *47:* 97–159.

Garn, S. M. 1955 Applications of pattern analysis to anthropometric data. Ann. N. Y. Acad. Sci., *63:* 537–552.

Garn, S. M., and C. G. Rohmann 1959 Communalities of the ossification centers of the hand and wrist. Am. J. Phys. Anthrop., *17:* 319–323.

——— 1960 Variability in the order of ossification of the bony centers of the hand and wrist. Ibid., *18:* 219–230.

——— 1961 The number of hand-wrist centers. Ibid., *18:* 293–299.

Garn, S. M., A. B. Lewis, K. Koski and D Polacheck 1958 The sex difference in tc calcification. J. Dent. Res., *37:* 561–567.

Garn, S. M., and Z. Shamir 1958 Methods Research in Human Growth. Charles Thomas, Springfield, Ill.

Guilford, J. P. 1950 Fundamental Statistics Psychology and Education, 2nd ed. McGr Hill, New York.

Krogman, W. M. 1941 Growth of Man. Tabu Biologicae, *20.*

Lacy, J. I. 1956 The evaluation of autono responses: toward a general solution. A N. Y. Acad. Sci., *67:* 125–163.

Moss, M. L., and C. R. Noback 1958 A lo tudinal study of digital epiphyseal fusion adolescence. Anat. Rec., *131:* 19–32.

Noback, C. R. 1954 The appearance of ossif tion centers and the fusion of bones. Am Phys. Anthrop., *12:* 63–70.

Noback, C. R., M. L. Moss and E. Leszczyn 1960 Digital epiphyseal fusion of the hanc adolescence: a longitudinal study. Ibid., 13–18.

O'Rahilly, R. 1953 A survey of carpal a tarsal anomalies. J. Bone Jt. Surg., *35A:* 6 642.

——— 1957 Developmental deviations in carpus and the tarsus. Clin. Orthopaed., 9–18.

Stevenson, P. H. 1924 Age order of epiphys union in man. Am. J. Phys. Anthrop., *7:* 93.

The Blood Vessels of the Heart of Gorilla Gorilla beringei

E. C. B. HALL-CRAGGS
Makerere University Medical School, Kampala, Uganda

In the section dealing with the thoracic viscera in “The Anatomy of the Gorilla” (Washburn, ’50) no mention is made of the anatomy of the vessels of the heart. However, Chase and De Garis (’39), in an extensive study of the coronary arteries in primates, dissected these vessels in two gorilla hearts. It seems most likely that these were obtained from coast gorillas, one having been lent by the late Mr. H. . Raven.

The addition of two further descriptions which includes a description of the coronary veins is considered worthwhile in view of the difficulty in obtaining this material and the fact that Gorilla gorilla beringei forms a definite sub-species (Coolidge, ’29).

Two hearts were examined. The first was that of an adult male gorilla and the second of an infant known to have died within two days of birth.

The adult heart was obtained from a male gorilla found dead near Kisoro in the District of Kigezi in Southern Uganda. A post-mortem examination was carried out by the District Veterinary Officer, probably within 12 hours of death, and the animal was eviscerated. The heart was preserved in a solution of formalin. The specimen was received approximately 6 hours later in Mbarara some 170 miles from Makerere College Medical School.

On examination the shape was found to have been considerably distorted by the container in which it had been transported and during evisceration the major part of both atria the venae cavae and the pulmonary veins had been removed. However, the auricles, ascending aorta, pulmonary trunk and ventricles, were in good condition.

An attempt was made to inject both coronary arteries with 10% formol saline and the organ was placed in a similar solution.

The weight of the animal was 134 kg and that of the specimen 730 gm.

The infant heart was kindly presented by Dr. G. Schaller. Although this again was somewhat deformed in fixation, it was complete, together with the other major thoracic organs. The specimen was obtained from Mount Mikeno in the Albert National Park, Belgian Congo.

The veins of the adult heart and the coronary arteries of both hearts, were displayed by naked eye dissection. The veins and arteries of the adult heart are described first and this is followed by a brief description of the arteries of the infant heart.

The cardiac veins (adult heart)

The great cardiac vein (vena cordis magna) is formed to the left of the pulmonary trunk by the union of 4 major tributaries draining the sternocostal surfaces of the left and right ventricles.

Within 1.0 cm of its formation it runs beneath the point of origin of the anterior interventricular and circumflex branches of the left coronary artery and continuing its course beneath the circumflex branch around the base of the left auricle it empties into the left end of the coronary sinus. It is joined at this point by the posterior vein of the left ventricle.

The posterior vein of the left ventricle (vena posterior ventriculi sinistri) is formed by several trunks draining the surface of the left ventricle. These join on reaching the atrioventricular sulcus. The short trunk so formed drains in company with the great vein into the left end of the coronary sinus. Two smaller but sizeable trunks were found draining the dorsal surface of the left ventricle directly into the coronary sinus.

The posterior interventricular vein (vena interventricularis posterior) is formed at the apex of the heart and runs across to the right in or near the interventricular sulcus. On reaching the atrioventricular sulcus it turns to the left and empties into the right end of the coronary sinus.

No vessel corresponding to the small cardiac vein (vena cordis parva) of human anatomy was found.

The anterior cardiac vein (vena cordis anterior) is formed at the apex and running along the right border of the right ventricle it empties directly into the right auricle in the atrioventricular sulcus. It is joined near its termination by a large trunk running from near the pulmonary conus across the right border of the ventricle.

The coronary sinus (sinus coronarius) lies deep in the dorsal atrioventricular sulcus buried in muscle of the atria. It opens by a foramen 1 cm in diameter immediately adjacent to the interatrial septum. Below and behind the foramen lies the valve of the inferior vena cava. There was no clearly marked valve of the coronary sinus.

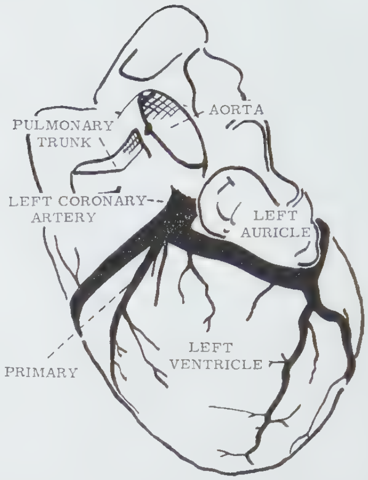


Fig. 1 View of left ventricle with the monary trunk and left auricle separated to s the bifurcation of the left coronary artery.

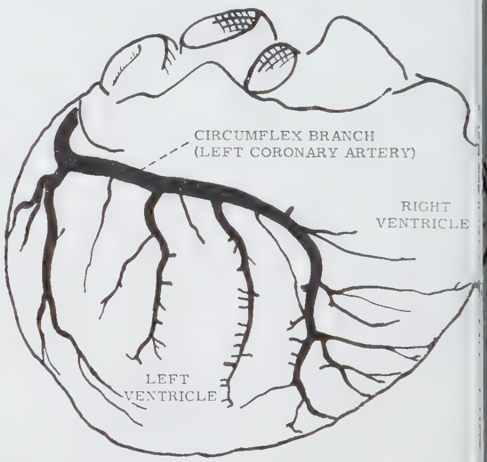


Fig. 2 Diaphragmatic view of left and ri ventricles to show the regions of both that supplied by the circumflex branch of the coronary artery.

The coronary arteries (adult heart)

The left coronary artery (Arteria coronaria (cordis) sinistra) takes origin from the left aortic sinus as a short stout trunk 0.8 cm in diameter and 1.0 cm in length. It bifurcates into circumflex and interventricular branches (fig. 1). Between the limbs of this bifurcation a third primary division is seen running down over the sternocostal surface of the left ventricle towards its left border. The circumflex branch lying in the atrioventricular sulcus runs around the base of the left auricle and then below the coronary sinus. On reaching the dorsal interventricular sulcus it runs down this towards the apex (fig. 2). Together with the third primary division three smaller branches supply the sternocostal surface of the left ventricle, a large bifurcate branch runs down the left border of the heart. Five branches and the main trunk supply the dorsal surface of the left ventricle and three branches and a terminal branch supply the dorsal and diaphragmatic surfaces of the rig ventricle. Branches to the left auricle a atria are given off in its course in t atrioventricular sulcus.

The interventricular branch runs do the anterior interventricular sulcus to t apex about which it turns (fig. 3). terminal branches supply a portion of t dorsal surface of the apex. The first rig branch runs to the base of the pulmona trunk and subsequent branches supply t sternocostal surface of the right ventric Branches from the left side run deep i

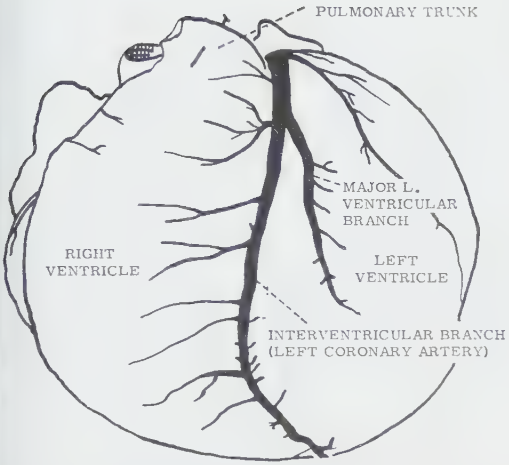

PULMONARY TRUNK
MAJOR L. VENTRICULAR BRANCH
RIGHT VENTRICLE
LEFT VENTRICLE
INTERVENTRICULAR BRANCH (LEFT CORONARY ARTERY)

Fig. 3 Ventral view of right and left ventricles to show the interventricular branch of the left coronary artery.

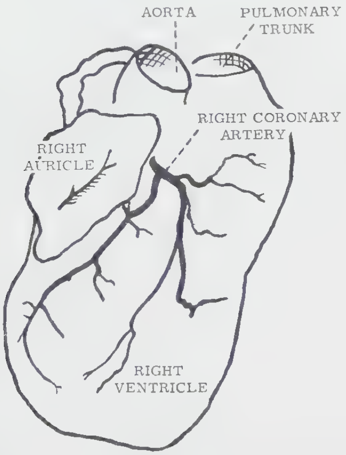


Fig. 4 View of right ventricle to show the distribution of the right coronary artery.

the muscle of the left ventricle. A major branch leaves the main trunk after 4.0 cm of its course to supply the sternocostal surface of the left ventricle.

The right coronary artery (Arteria coronaria (cordis) dextra) takes origin from the ventral aortic sinus (fig. 4). Its caliber is small relative to the left artery being only 2.5 mm in diameter. A small branch is given off almost immediately to the pulmonary conus. The main vessel running behind the pulmonary conus bifurcates after 1.5 cm into two divisions of approximately equal caliber. The posterior division continues its course in the atrioventricular groove sending branches to the right auricle and right ventricle. It terminates on the right half of the diaphragmatic surface of the right ventricle. The anterior division runs down the right border of the right ventricle towards the diaphragmatic surface supplying the adjacent surfaces of the ventricle.

The coronary arteries (infant heart)

The coronary arteries of the infant heart bear a very close resemblance to those of the adult. The anterior interventricular branch of the left coronary artery runs down the interventricular sulcus up to and around the apex. Its first branch is a large one to the pulmonary conus. There is no major left branch. A third primary division is present at the bifurcation of the left coronary artery but there are no minor ventricular branches of the circumflex branch as it curves around the base of the left auricle. At the left border of the heart two large branches as opposed to a large bifurcate branch are seen leaving the circumflex branch. Three further small ventricular branches and a major branch to the right auricle are given off by this artery before it runs down in the posterior interventricular sulcus. Here two major branches are given off to the right ventricle.

The right coronary artery is again found to be small and bifurcate, the posterior branch running a short course in the atrioventricular groove and the anterior supplying a small region of the right ventricle.

DISCUSSION

The venous pattern follows very closely that described for the human heart by Sobotta ('57) and calls for little comment.

The arterial distributions encountered do, however, differ significantly from the two descriptions already available, and in view of the established variations in human distribution they are discussed more fully.

It would appear that the descriptions given here of the left coronary artery correspond in most respects with that given by Chase and De Garis ('39) although the details of the anterior and posterior interventricular branches in the present specimens differ, in that in one specimen the former possesses a major left branch, and that in both specimens the latter is represented by a single trunk rather than a leash of vessels.

The description of the right coronary, however, reveals a dissimilar pattern. Chase and De Garis ('39) describe in their first specimen a vessel curving downwards over the conus which it supplies by a branch, and continuing around to the dorsal surface where a long ventricular branch reaches near to the apex. A further right ventricular branch is described as running down the margo acutus reaching again near to the apex. In their second specimen a small offset to the conus arises directly from the aorta, the main trunk lies further from the atrioventricular sulcus and supplies a greater density of branches to the conus and the ventral aspect of the right ventricle, and finally the ventricular branch running down the margo acutus is reduced to two slender twigs.

In the present specimens the right coronary is remarkably small in size. It divides into two trunks of equal size, one keeping close to the atrioventricular sulcus and one lying more anteriorly and sending branches to the right ventricle below the conus. There are no long ventricular branches, both divisions barely reaching the diaphragmatic surface of the right ventricle. The region between this point and the apex is supplied by long branches of the posterior interventricular branch of the left coronary artery.

Schlesinger ('40) related the anatomical pattern of human arteries to pathological conditions. Analyzing 225 hearts from subjects over 35 years of age he described three distinct patterns, the criterion being the supply of the so-called "crux" of the heart where the left and right ventricles, left and right auricles, and the interventricular and interauricular septa all meet.

In the first group of hearts in this series the right coronary artery supplies a large part of the posterior wall of the left ventricle and from it arises the posterior descending or interventricular artery. In the second group the circulation is more balanced, the ventricles being supplied by their corresponding arteries and the right artery, although supplying the posterior half of the interventricular septum, gives no significant branches to the post surface of the left ventricle. In the third group both the left circumflex coronary artery and the right coronary artery may reach the crux and terminate in parallel posterior descending or interventricular branches or in other hearts the posterior descending coronary artery arises solely from the left circumflex coronary artery.

This third group formed 18% of the human hearts examined and it seems clear that both the patterns described by Chase and De Garis ('39) and those described for the present specimens would fall into this group.

Brink ('49) examined the coronary circulation in 33 human hearts. Fifteen of these were from Bantu subjects. He drew attention to the presence in 12 of these of a third primary division of the left coronary artery. The third primary division encountered in the present specimens corresponds to this vessel. Chase and De Garis ('39) however, did not describe a similar structure in either of their gorilla hearts. The significance of this third primary division of the left coronary artery has, however, been questioned by Singer ('59). Observations based on dissections of 278 human hearts, 86 of which were from Bantu subjects, seem to indicate that the presence of a third primary division is an individual and not a racial variation. Singer suggests that the third primary division is no more than a variation of a major left ventricular artery normally arising from the circumflex branch of the left coronary artery. In the adult gorilla specimen described both major and minor left ventricular arteries and a third primary division were represented. In the infant gorilla heart a third primary division but no major or minor left ventricular branches were found.

SUMMARY

The cardiac veins and coronary arteries of specimens obtained from Gorilla gorilla beringei are described. The arrangement of the coronary arteries is compared with that described by Chase and De Garis ('39). Comparisons are also drawn with human coronary artery patterns. Particular reference is made to the left coronary artery preponderance found and the pres-

ence and significance of a third primary division.

ACKNOWLEDGMENT

I must acknowledge the great help given to me in the preparation of this paper by Professor A. Galloway.

LITERATURE CITED

Brink, A. J. 1949 The Coronary Vessels in the Bantu: A preliminary report on the Coronary Artery Pattern in the Adult Bantu. Clin. Proc., *8:* 137–149.

Chase, R. E., and C. F. De Garis 1939 Arteriae Coronariae (cordis) in the Higher Primates. Am. J. Phys. Anthrop., *24:* 427–448.

Coolidge, H. J. 1929 A Revision of the Genus Gorilla. Mem. Mus. Comp. Zool. Harvard, 293–381.

Schlesinger, M. J. 1940 Relation of Anatomic Pattern to Pathological Conditions of the Coronary Arteries. Arch. Path., *30:* 403–415.

Singer, R. 1959 The Coronary Arteries of the Bantu Heart. S. A. Med. J., *33:* 310–315.

Sobotta-Uhlenhuth 1957 Atlas of Descriptive Anatomy. Hafner Publishing Co., Inc., New York.

Washburn, S. L. 1950 In The Anatomy of the Gorilla. Columbia University Press, New York.

keletal Development of Hand and Wrist in innish Children[1]

KALEVI KOSKI, JOHANNES HAATAJA AND MARJA LAPPALAINEN
Department of Anatomy, University of Turku, and
Institute of Dentistry, University of Helsinki, Finland

Differences exist between different pop- lations as to the speed of skeletal development, and the standards employed n assessing the maturational stage of the keletal system must therefore be based n samples derived from the population or which they will be used (cf. Falkner, 58). This problem was encountered by s when trying to assess the skeletal development of orthodontic patients, whose iagnosis and treatment plan may often e affected by information gained through his procedure (cf. De Coster, '39). In ack of suitable norms for the Finnish opulation the atlas of Greulich and Pyle ('50) was used as reference, but accumu- ation of material and experience increas- ngly pointed towards a general trend for innish children to lag behind their American age mates in skeletal development.

In the course of a study, primarily con- ucted for other purposes, a small cross- ectional sample of Finnish children were ubjected to hand and wrist roentgenog- aphy, and the resulting sample of radiograms enabled us to make a pilot survey on the normal skeletal development in our child population (Koski, Haataja and Lappalainen, '59). During this study atten- ion was also paid to the systematic error n assessment between several observers, a problem that has also been considered by Mainland ('53). Furthermore, a study on the hand and wrist radiograms of orthodontic patients was made in order to see whether their skeletal development, as a group, shows any significant deviation from normal development (Haataja and Lappalainen, '60). As no significant difference between the orthodontic and normal sample was found, it was felt safe to combine both samples for the present report on the skeletal development of Finnish children.

MATERIAL AND METHOD

The first sample consisted of 156 children from primary and secondary schools in Helsinki. These children were enrolled by classes, the aim being to get samples of children representing certain developmental stages of the dentition. The ages of children ranged from 7 to 17 years, centering around 11 and 14–15 years; sexes were about equally represented.

The second sample included 404 orthodontic patients from the Institute of Dentistry, ranging from 5 to 18 years of age, two thirds of the children being from 10 to 15 years old. There were about twice as many girls as boys in this group.

The first, "normal" sample included a few individuals, whose skeletal age was found to deviate from their chronological age very markedly. Since the children were not given a medical examination, the possibility remained that the extreme deviations were associated with some pathological phenomena. In order to safeguard our sample a criterion for excluding extreme cases was adopted after consulting the figures of standard deviations of skeletal age in the sample of Greulich and Pyle. We decided to exclude all children whose bone age deviated more than 30 months from the appropriate standard in the Greulich and Pyle atlas. This time interval is approximately three times the average S.D. found by Greulich and Pyle in the age groups from 11 to 15 years, which form the majority in our samples. This criterion, which was also employed in our second sample, gives our final study sample a range similar to that of the Greulich and Pyle sample. The procedure resulted in the exclusion of 24 children

---

[1] This work has been aided in part by a grant from the Sigrid Juselius Foundation.

from the total material, leaving us with a final study sample of 530 children (see table 1).

The radiograms were all taken of the right hand, since possible asymmetric development has been found to be nonsignificant (Baer and Durkatz, '57). An ordinary dental x-ray machine was used, the focus-film distance was 60 cm, and the beam was directed on the center of the metacarpal area.

The reading of the films was done in a clinical fashion, whereby attention was paid only to the standard pictures and the adjoining explanations of the atlas. The skeletal age was determined to the nearest half a year, interpolating, when necessary, between two successive norms of the atlas.

Systematic error of the method

The accepted films of the first sample, 150 in number, were assessed by all three authors independently. The senior author had some previous experience in estimating the skeletal age from hand and wrist radiograms, whereas the two other observers were instructed by him in the beginning of the study.

The differences between paired observations ranged from zero to 1.5 years. The extreme difference, 1.5 years, was encountered in only 10 instances out of 450. A difference of 1.0 year occurred in 36, and a difference of 0.5 year in 180 instances, while in 224 cases out of 450 paired observations an agreement was reached. All three observers agreed 46 cases out of 150.

TABLE 1

The distribution of the children as to age and sex

Age	Boys	Girls
5	1	1
6	1	2
7	5	11
8	8	12
9	10	17
10	6	14
11	34	46
12	27	51
13	23	35
14	37	44
15	28	43
16	15	20
17	7	17
18	3	12
Total	205	325

The mean intrapair differences and t standard errors of these means, in yea were as follows:

K.K — J.H.: $\bar{x} = +0.15$; $s_{\bar{x}} = 0.04$;
K.K. — M.L.: $\bar{x} = +0.17$; $s_{\bar{x}} = 0.03$;
J.H. — M.L.: $\bar{x} = -0.01$; $s_{\bar{x}} = 0.04$.

In the two first cases the mean diff ence is clearly statistically significant, i. there was a clear tendency for the seni author to give higher skeletal age es mates than the other assessors; betwe the two others no systematic differen was found.

In the second sample, which was a sessed by one observer (M.L.) throughou her observations were checked in 1 cases by another assessor (J.H.) and, in the first sample, no systematic diffe ence was found between their estimate

Since all the films were assessed M.L., her readings were used in the pre ent study.

RESULTS

The mean differences in the skeletal a between our sample and the standards Greulich and Pyle, together with the stan ard deviations and standard errors of t means, separately for boys and girls, f the total samples, are given in table 2.

The mean differences were calculat for yearly age groups of both sexes, to and were plotted on a graph (fig. 1). T curves connecting the points are rath irregular. When the lowest and highe age groups are not considered, the grou from 11 to 15 years which include su stantial numbers of children reveal n clear trend towards an increasing or d creasing difference with age. Therefor and because of the small number of ch dren in the majority of the age group it was felt that one total mean for eac sex would suffice to indicate the di

TABLE 2

The mean deviation of the skeletal age of Finni children from the norms of Greulich and Pyle, in months

	N	$\bar{x}$	s_x	$s_{\bar{x}}$
Boys	205	−7.8	11.33	0.7
Girls	325	−5.9	11.70	0.6

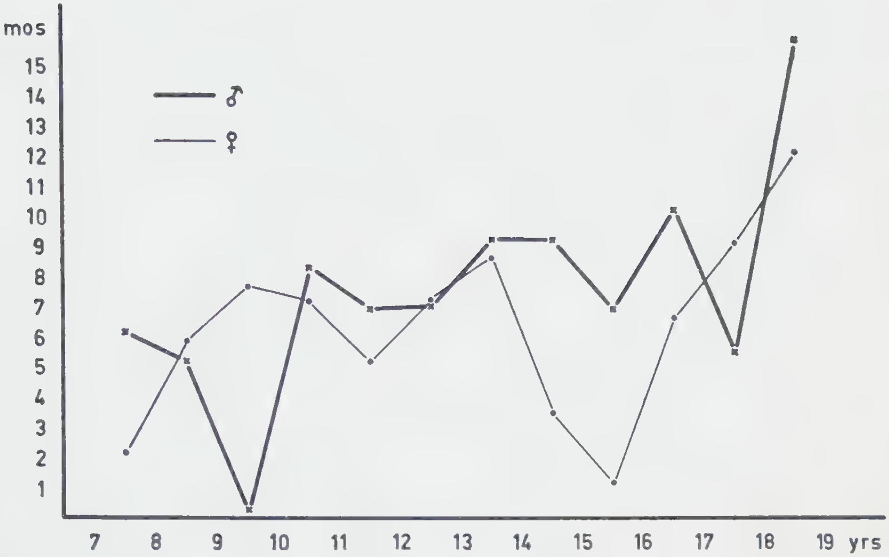


Fig. 1 The mean deviations of skeletal age of Finnish children from the norms of Greulich and Pyle in yearly age groups, for both sexes.

ference between the Finnish and American children.

The difference between the sexes barely escapes being statistically significant at the 5% risk level ($t = 1.92$, $0.1 > P > 0.05$).

COMMENTS

The inspectional method of estimating the skeletal age, although widely used because of its convenience, has been criticized from time to time (Acheson, '54, Falkner, '58), mostly from the researcher's point of view. Mainland ('53) published a pilot study on the subjective errors of the method and discussed his findings, concluding that more information is needed on these aspects.

In the present study a small systematic error was found between a somewhat experienced and two inexperienced assessors, while the latter two appeared to agree in their estimations of the skeletal age. The systematic error was quite small, only about two months. In view of the magnitude of the standard deviation found in normal child populations (Greulich and Pyle, '50), averaging ca. 10 months, this systematic error appears negligible, for all practical purposes. Our results, then, support Falkner's ('58) opinion of the validity of the inspectional method in clinical use.

It was interesting to see that the systematic error found here was of the same magnitude as that found in Mainland's ('53) study, and to the same direction, i.e., the more experienced observer tended to estimate the skeletal age higher than the less experienced observers.

The differences in skeletal development between Finnish and American children varied considerably in different age classes. It is felt that this must be a sampling effect, as it is difficult to find any biological explanation for the fluctuations found in our material in this respect.

On an average, the Finnish children tend to lag behind their American age mates in the skeletal development, the difference being of the order of half a year. Both samples compared here are urban children which permits the comparison. It should be noted that the sample of children on which the atlas of Greulich and Pyle is based belongs to an earlier generation than our sample. The secular trend would thus be likely to increase the difference if studied between an American sample of the same generation as ours, though the effect of the secular trend is hard to estimate. On the other hand, if the systematic error found in the present study is considered it might be said that the figures given here are too high, since the lowest estimates were used. The net result of weighting these two antagonistic factors may well be zero, and the figures may thus be taken as fairly reliable indicators of an existing difference between the two child populations.

Although our approach was clinical and the assessment was done accordingly, it seems safe to conclude that the results of this study stress the need for population-specific norms when the inspectional method is employed.

SUMMARY

A study on the skeletal development of the hand and wrist of 530 apparently healthy Finnish children, ranging from 5 to 18 years of age, resulted in the following findings:

1. A small systematic error was found between one somewhat experienced and two inexperienced assessors when using the inspectional method and the atlas of Greulich and Pyle ('50). The experienced assessor's estimates were, on an average, ca. two months higher than the estimates of the two other observers who were in agreement. A systematic error of this magnitude cannot be considered to invalidate the method for clinical use.

2. The skeletal development of Finnish children was found to be slower than that of American children, represented by the sample of Greulich and Pyle. The mea difference for boys was 7.8 months, f girls 5.9 months; the sex difference wa not significant at the 5% risk level. Th finding indicates a need for populatio specific norms when using the inspection method.

LITERATURE CITED

Acheson. R. M. 1954 A method of assessi skeletal maturity from radiographs. J. Ana *88:* 488–496.

Baer, M. J., and J. Durkatz 1957 Bilater asymmetry in skeletal maturation of the han and wrist: a roentgenographic analysis. Ar J. Phys. Anthrop., *15:* 181–196.

De Coster, L. 1939 Lack of synchronism bone growth and tooth eruption as an aetiolo ical factor of malocclusion. Eur. Orthod. So Rep. *1938:* 166–176.

Falkner, F. 1958 Skeletal maturation; an a praisal of concept and method. Am. J. Phy Anthrop., *16:* 381–396.

Greulich, W. W., and S. I. Pyle 1950 Atlas Skeletal Development of the Hand and Wris Stanford University Press, Stanford.

Haataja, J., and M. Lappalainen 1960 On th osseous development of the hand and th wrist of children undergoing orthodontic trea ment. Suom. hammaslääk. toim. (Proc. Fin Dent. Soc.), *56:* 429–436. (In Finnish.)

Koski, K., J. Haataja and M. Lappalainen 19 On the skeletal (hand and wrist) developme of Finnish children. Suom. hammaslääk. toim *55:* 236–243. (In Finnish.)

Mainland, D. 1953 Evaluation of the skelet age method of estimating children's develo ment. I. Systematic errors in the assessme of roentgenograms. Pediatrics, *12:* 114–129.

he Blood Groups of the Kutchin Indians at ld Crow, Yukon Territory[1]

M. LEWIS,[2] J. A. HILDES,[3] H. KAITA[4] AND B. CHOWN[5]
Rh Laboratory, Winnipeg, Man.

This report concerns the blood groups nd the blood group genes of the Indian habitants of the village of Old Crow, here physiological studies were conucted and blood samples collected by ving et al. ('59) in the summer of 1958. village of 165 inhabitants, Old Crow is ituated near the junction of the Old Crow nd Porcupine Rivers in the Yukon Terriory of Canada, about 35 miles east of the laska-Yukon border and 75 miles north f the Arctic Circle. To the people from hom the present population derives, arly white explorers, travelers and tradrs gave the names Kutchin and Loucheux, he former a native word meaning simply the people," the latter a French word, the xact connotation of which is obscure in ts application to these people. The Kuthin are the most north-westerly Athapaskan-speaking people; when first known hey were essentially the people of the Yukon River Basin.

According to Mooney ('28) the population before contact with Whites was estimated at 3,000. They were bordered on he south by the Tlinkit Indians, on the east by Hare and Nahani tribes who, like the Kutchin, belong to the Athapaskan language group and to the north by the Eskimo. There is no record of Eskimos marrying into the population, and so far as Whites are concerned, while the first recorded white contact was made by Alexander Mackenzie in 1789, continuous contact did not commence until around 1840. Jenness ('58) estimates that perhaps 700 Kutchin are living within the borders of Canada at the present time. There are also settlements of them about Fort Yukon, Chandalar and Circle in north-east Alaska.

Physically the population of Old Crow is essentially isolated. Genetically it may be looked upon as a breeding isolate into which some white genes have been introduced. This became apparent when a detailed genealogy was drawn up, a remembered record involving 5 generations and extending back to about 1850 or earlier. Eleven white men are known to have married into it in the last three generations, while the gene data suggest that white blood *may* have been introduced even earlier.

Whatever the regulation of mating may have been in the past, today no breeding pattern is discernible. However, by necessity, there is a greater frequency of cousin marriages than is wont to occur in larger populations: of the 54 matings currently in the child-bearing period, one quarter are between cousins of some degree, mostly second-cousins but in one instance first, as illustrated in the excerpts from the population genealogy given in figures 1a and 1b.

The facts given us by our informants allow us to trace the population back at least 5 generations in most cases as mentioned and illustrated. Two sets of siblings in generation I have given rise to 91 of the people tested, 26 of these being descended from both families. In the newest generation which comprises some 55 youngsters, there are only three whose ancestry can be traced without finding any two ancestors related. Allowing for the known relationships in generation I, the Indian gene pool in that generation could be no greater than 230 for any given blood group locus. However, a study of the

---

[1] Editor's note: This paper was presented at the 28th Annual Meeting of the American Association of Physical Anthropologists, 1959. Its publication was delayed by the editor in anticipation of use in a centennial volume which did not materialize.
William S. Laughlin

[2] Rh Laboratory and Department of Pediatrics, University of Manitoba, Canada.

[3] Defense Research Board Arctic Medical Research Unit, Department of Physiology, University of Manitoba.

[4] See footnote 2.

[5] See footnote 2.

EXCERPT FROM POPULATION GENEALOGY ILLUSTRATING COUSIN MARRIAGES

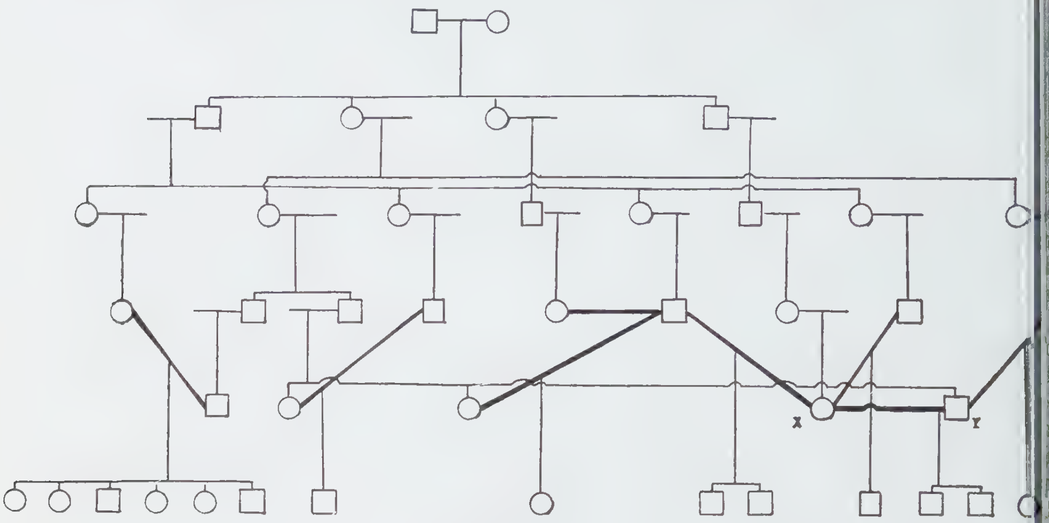


Figure 1a

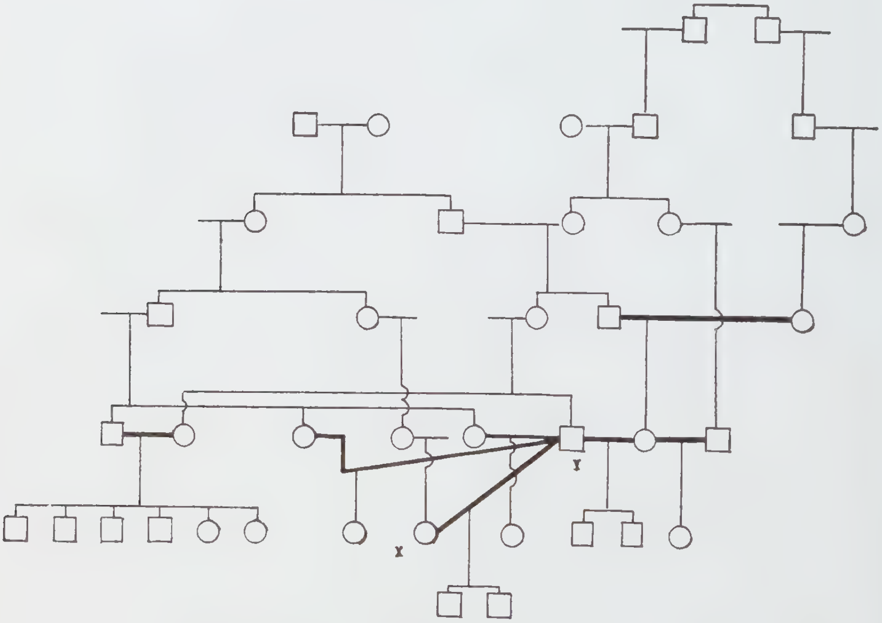


Figure 1b

Fig. 1a and 1b. The heavy bars in figures 1a and 1b indicate cousin matings. The two persc X and Y are the same in both figures, figure 1a illustrating the cousin matings in the sibship of on his father's side, and figure 1b on his mother's side. The figures have been stripped of siblir who have mated outside the family line. There were other relationships between some of the spous not in the direct family descent.

genealogy reveals that a large proportion of these have been lost, and that in the existing population a maximum of 70 can be extant. It is then the sort of population in which we might expect to see the e fects of genetic drift; those effects see evident in the skewness of the frequenci of some of the blood group genes.

MATERIALS AND METHODS

On two occasions during September
58 venous blood samples were collected
m a total of 114 persons. The samples
re taken into sterile tubes containing
ever's solution and forwarded immedi-
ly to our laboratory in Winnipeg where
y were tested within 4 days of collec-
n. The section of the population not
luded in the study was mostly children
pre-school age whose parents and sib-
gs were included.

For a description of the sera and meth-
s used the reader is referred to a study
the Copper Eskimo (Chown and Lewis,
) from which the present study differs
y in the following substitutions and
issions: anti-S (Hog), indirect Coombs;
i-C+C^{w} (Bill), anti-C^{w} (Kra) and anti-D
no), capillary; anti-E+E^{w} (McL), capil-
y papain; no tests were made for Fy^{b},
^{a}, Lu^{b}, Vw, He, Wr^{a}, Be^{a}, By^{a} or Secre-
status.

The gene frequencies for the MNSs
tem were determined by the method
en by Mourant ('54) for populations
ted with the 4 anti-sera. For the P sys-
n the square root method was used, and
the Rh system, a straight gene count.

RESULTS

To simplify matters the results are set
t in the order of increasing complexity
her than in the usual manner.

ABO system. Of the 114 persons tested 113 were group O; one, a child, was group B. The child's maternal grandparents were both group O so we attribute the B to his white father.

Kell system. All 114 reacted K− k+ Kp(a−b+) and are therefore assumed to be $k^{b} \cdot k^{b}$.

Duffy system. All 114 reacted Fy(a+).

Diego system. All 114 reacted Di(a−).

Yt^{a}. 113 group O were tested and found to be Yt(a+).

Lewis system. 113 group O were tested; 9 were Le(a+), 104 Le(a−). The 9 Le(a+) were members of three family groups. The Lewis system is in such a state of upheaval that it seems pointless to attempt to determine gene frequencies.

TABLE 1

The MN groups

Phenotype	"Pureblood"		All	
	Number	Frequency	Number	Frequency
MM	55	0.5978	58	0.5088
MN	34	0.3696	53	0.4649
NN	3	0.0326	3	0.0263
	92	1.0000	114	1.0000
Gene frequencies				
M		0.7826		0.7413
N		0.2174		0.2587
		1.0000		1.0000

TABLE 2

The Ss groups

Phenotype	"Pureblood"		All	
	Number	Frequency	Number	Frequency
SS	10	0.1087	14	0.1228
Ss	31	0.3369	45	0.3947
ss	51	0.5544	55	0.4825
	92	1.0000	114	1.0000
Gene frequencies				
S		0.2771		0.3201
s		0.7229		0.6799
		1.0000		1.0000

TABLE 3

The MNSs groups

Phenotype	"Pureblood"		All	
	Number	Frequency	Number	Frequency
MMSS	3	0.0326	4	0.0351
MMSs	16	0.1739	18	0.1579
MMss	36	0.3913	36	0.3158
MNSS	7	0.0761	10	0.0877
MNSs	13	0.1413	25	0.2193
MNss	14	0.1522	18	0.1579
NNSS	0	0.0000	0	0.0000
NNSs	2	0.0217	2	0.0175
NNss	1	0.0109	1	0.0088
	92	1.0000	114	1.0000
Gene frequencies				
MS		0.1895		0.2109
Ms		0.5931		0.5304
NS		0.0876		0.1092
Ns		0.1298		0.1495
		1.0000		1.0000

TABLE 4

The P groups

Phenotype	Possible genotype	"Pureblood"		All	
		Number	Frequency	Number	Frequency
P+	$P_1 \cdot P_1$ $P_1 \cdot P_2$ $P_1 \cdot p$	27	0.2935	36	0.3158
P− Tj(a+)	$P_2 \cdot P_2$ $P_2 \cdot p$	65	0.7065	78	0.6842
		92	1.0000	114	1.0000
			Gene frequencies		
	P_1		0.1595		0.1728
	$P_2 + p$		0.8405		0.8272
			1.0000		1.0000

TABLE 5

The Rh groups

Reaction CcDEe	Possible genotype	"Pureblood"		All	
		Number	Frequency	Number	Frequency
+ − + − +	*CDe·CDe* *CDe·Cde*	4	0.0435	8	0.0702
− + + + −	*cDE·cDE* *cDE·cdE*	54	0.5869	57	0.5000
+ + + + +	*CDe·cDE* *Cde·cDE* *CDe·cdE* *CDE·cDe* *CDE·cde* *CdE·cDe*	27	0.2935	40	0.3509
+ + + − +	*Cde·cDe* *CDe·cde* *CDe·cDe*	3[1]	0.0326	3	0.0263
− + + + +	*cDE·cDe* *cDE·cde* *cdE·cDe*	3[1]	0.0326	5	0.0438
+ + + + −	*CDE·cDE* *CDE·cdE* *CdE·cDE*	1	0.0109	1	0.0088
		92	1.0000	114	1.0000
			Gene frequencies		
	CDe + *Cde*		0.2066		0.2588
	cDE + *cdE*		0.7554[2]		0.7018
	cDe + *cde*		0.0326		0.0350
	CDE + *CdE*		0.0054		0.0044
			1.0000		1.0000

---

[1] The 6 persons who constitute the frequency for *cDe* + *cde* of 0.0326, appear in figure 3. This frequency then we believe to represent *cDe* alone.

[2] 0.7554 is given for the sum of the frequencies for *cDE* + *cdE*. There is no evidence for the presence of *cdE* in this population nor is it an Amerindian trait.

The results for the *MNSs*, *P* and *Rh systems* are set out in tables 1 to 5. Two sets of data are given in each table; one for the "purebloods" as determined by the genealogy, the other for the whole population sample. Additional observations concerning these three systems are as follows:

MNSs system. All 114 were Mg− and Mi(a−).

P system. Samples reacting P− were tested with anti-Tj^a; all were Tj(a+).

Rh *system.* Samples reacting c+ e+ were tested with anti-V; all were V−. All 114 were C^w−.

There were no irregularities in the inheritance of any of the blood group genes.

DISCUSSION

Considering the "pureblood" fraction of this population, deviations from what might be expected are to be seen in the ABO, MNSs, Rh and Diego systems. According to Boyd ('39), Grant in 1938 tested 28 Loucheux of the Mackenzie Basin and found them all to be group O. However, we have found in other Athapaskan Indians (unpublished data) the frequency for the gene *A* to be from .10 to .15 while others have also found *A* in Indians of Athapaskan stock, for example .13 for Hupa (Hulse, '59) and .03 to .08 in three Alaskan settlements (Corcoran, Allen, Allison and Blumberg, '59). The Old Crow population lacks *A;* this we would ascribe to drift.

In the MNSs system the frequency for *NS* of .09 is the highest of any Indian population we have studied and is considerably higher than that demonstrated in their close relatives studied by Corcoran et al. ('59). A frequency of .09 is essentially the same as that found in Whites; it can hardly be ascribed to the small number of unknown Whites who might have bred into the population. Again we think drift the most likely explanation.

In the Rh system, the frequency for the gene *cDE* of .76 is the highest, so far as we know, of any recorded population, the closest to it being .61 for the British Columbia Coastal Indians (Mourant, '54) and .62 for 110 Alaskan Athapaskans living at Fort Yukon (Corcoran et al., '59). The replacement of *CDe* by *cDE* is best explained by drift.

In the Diego system, the gene Di^a is not present; the only other Indian populations from which it has been reported to be absent are the Winikina-Warrau at the mouth of the Orinoco (Layrisse, Arends and Wilbert, '58) and the Tlinkit (Corcoran et al., '59). Corcoran et al. ('59) found only one Di(a+) in 206 Alaskan Athapaskans. Although this lack of Di^a in the present population could be explained by drift, the similar findings of Corcoran et al. may indicate some other explanation.

Such is the evidence that, in this small breeding isolate, the effect of drift is manifest in three, and possibly in 4 blood group systems. In view of this it would be fruitless to try to compare the Old Crow blood group results with studies on other populations with the aim of establishing racial relationships. Equally it would be a serious error to use the figures as representative of the Athapaskan at large.

So much for the general population genetics; for the serologist one family (fig. 2) is of particular interest. The propositus, III-2, is Le(a+). Our experience with Indians and Eskimos has led us to believe that the gene Le^a is not present in the purebloods, and that its presence indicates the invasion of the population by a foreign gene, usually white. Accordingly, although the propositus was born in 1890 and is believed to be pureblood, the presence of Le^a suggests that she is not. This suggestion gains support from consideration of the reaction of her blood with anti-D of the Rh system.

When the tests were being done it was noted that 2 of the 114 samples took a much longer time to agglutinate with anti-D serum than did the others; their Rh reactions were C+ c+ D+ E− e+. The three possible genotypes for these reactions are *CDe·cde*, *CDe·cDe*, and *Cde·cDe.* In 1955 while studying a hybrid Cree population (Chown and Lewis, '56, '57) we observed that some members of a large sibship reacted weakly with anti-D; all of the weak-reactors had, partnered with their D-positive gene, the D-negative gene *Cde.* Ceppellini, Dunn and Turri ('55) had made the same observation on the people of the

GENEALOGY ENCOMPASSING THE TWO "WEAK D" REACTORS

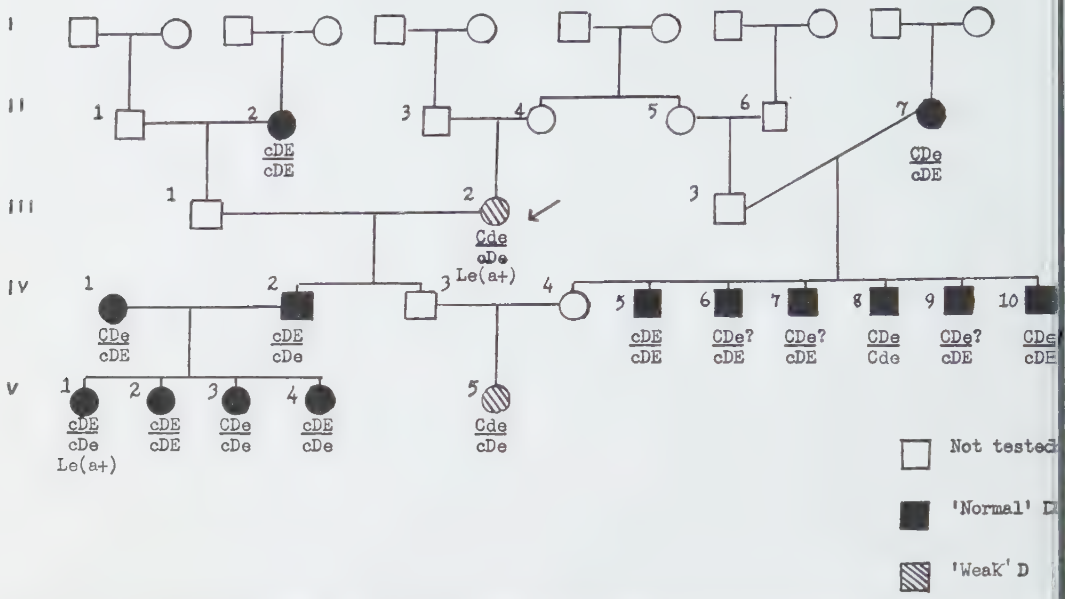


Fig. 2 III-2 and V-5 were the only members of the population whose blood reacted weakly wit anti-D, as D-positive bloods may do when *D* is partnered with *Cde*. IV-6,7,9 or 10 could carry *CD* or *Cde* hence the question mark. All members Le(a−) unless otherwise indicated.

Ghetto in Rome, and Levine, Celano, McGee, Muschel and Griset ('57) reported on this same phenomenon. However, we concluded at that time, and further experience has borne this out, that "different D antigens react differently with the same *Cde* and [this] implies an inherent variability of the D antigen." We have observed that as one goes from Mongoloid to Caucasoid to Negroid there is a steady diminution in the average strength of reaction of the D antigen. The difference between Negroid and Caucasoid is well recognized, D^u being common in the Negroid. However, the difference between Mongoloid and Caucasoid is scarcely noticed unless a method involving time or strength of reaction be used; then it is quite striking. The fact then that the reaction of III-2 and V-5 with anti-D is delayed suggests two things: first that one of the genes present is *Cde*, and second that the D-carrying gene can be depressed by that *Cde* and is therefore potentially weak and more likely of white than of Indian origin. This then lends support to the suggestion made by the presence of Le^a, namely that III-2 has a white ancestor.

The above argument also illustrates another serological fact, namely that th strength of reaction may at times allow one to determine the genotype directl from the phenotype. The above reaction indicate that of the three possible genotypes the propositus and her grandaughter, V-5, must be *Cde·cDe*. If this is s then IV-2 and V-1, 3 and 4 carry *cDe*. Further IV-8 must carry *Cde* while IV-6, 7, 9 and 10 may carry *Cde* rather than *CDe* but if they do the partnered D, being Indian, is not depressed. Direct proof o these genotypes of course depends upon continued recombination which may in future generations yield persons of the genotypes *Cde·Cde* and *cDe·cDe*.

CONCLUSIONS

Evidence has been presented that in the small breeding isolate under study the effect of genetic drift is manifest in three and possibly 4 blood group systems.

Attention is drawn to the fact that the strength of reaction of the D antigen may at times indicate the probable genotype and also to the difference in strength o his antigen as between Mongoloid and Caucasoid.

SUMMARY

One hundred and fourteen Kutchin Indians living at Old Crow, Yukon Territory were the subjects of a blood group study; 92 of these were designated as pureblood. The gene frequencies for the "pureblood" were as follows: O 1.0000; *MS* .1895, *Ms* 5931, *NS* .0876, *Ns* .1298; P_1 .1595, P_2+p 8405; *CDe+Cde* .2066, *cDE+cdE* .7554, *cDe+cde* .0326, *CDE+CdE* .0054; k^b 1.0000. Other blood groupings were: Fy(a+) 1.0000; Di(a−) 1.0000; Yt(a+) 1.0000; Mi(a−) 1.0000; Le (a+) .0543, Le(a−) .9457. A detailed genealogy reveals that cousin matings are not uncommon and that the population is essentially a breeding isolate so far as Indian genes are concerned. The lack of *A* and Di^a, the relatively high frequency of *NS* and the replacement of *CDe* by *cDE* are assumed to be evidence of genetic drift. Evidence is given for the presence of the genes *cDe* and *Cde* and attention is drawn to the fact that the strength of the D antigen seems greater in Mongoloids than in Caucasoids. The addition of white genes introduces *B* and increases the frequencies of *N*, *S*, P_1, *CDe+Cde*, *cDe+cde* and Le(a+).

ACKNOWLEDGMENTS

We are happy to acknowledge the continued support of the National Museum of Canada through Dr. Jacques Rousseau. For gifts of rare sera we are grateful to Drs. E. R. Giblett, F. H. Allen, Jr., J. Mohn and P. Schmidt. We are deeply indebted to Mrs. Effie Linklater of Old Crow for her assistance with the genealogy and to her fellow men for their cooperation. We are also indebted to Dr. Laurence Irving and his colleagues whose physiological expedition made the present study possible and who have shown a keen interest in it.

LITERATURE CITED

Boyd, W. C. 1939 Blood groups of American Indians. Am. J. Phys. Anthrop., *25:* 215–235.

Ceppellini, R., L. C. Dunn and M. Turri 1955 An interaction between alleles at the Rh locus in man which weakens the reactivity of the Rh_o factor (D^u). Proc. Nat. Acad. Sci., Wash., *41:* 283–288.

Chown, B., and M. Lewis 1956 The blood group genes of the Cree Indians and the Eskimos of the Ungava district of Canada. Am. J. Phys. Anthrop., *14:* 215–224.

——— 1957 Occurrence of D^u type of reaction when CDe or cDE is partnered with Cde. Ann. Human Genet., *22:* 58–64.

——— 1959 The blood group genes of the Copper Eskimo. Am. J. Phys. Anthrop., in press.

Corcoran, P. A., F. H. Allen, Jr., A. C. Allison and B. S. Blumberg 1959 Blood groups of Alaskan Eskimos and Indians. Am. J. Phys. Anthrop., *17:* 187–193.

Hulse, F. S. 1960 Ripples on a gene pool: the shifting frequencies of blood-type alleles among the Indians of the Hupa reservation. Am. J. Phys. Anthrop., *18:* 141–152.

Irving, L., K. L. Andersen, A. Bolstad, R. W. Elsner, J. A. Hildes, Y. Lyning, J. D. Nelms, L. J. Peyton and R. D. Whaley 1959 Cold adaptation in Arctic Indians. To be published.

Jenness, D. 1958 Indians of Canada. Queen's Printer, Ottawa.

Layrisse, M., T. Arends and J. Wilbert 1958 Peculiar distribution of the Diego factor among the Warrau. Nature, *181:* 118–119.

Levine, P., M. Celano, R. McGee, L. H. Muschel and T. A. Griset 1957 D^u and gene interaction in a family study. Papers in dedication of P. H. Andresen's 60th birthday (Munksgaard, Copenhagen).

Mooney, J. 1929 Aboriginal populations of America. Smithsonian Institution, Misc. Coll., *80*, Wash.

Mourant, A. E. 1954 The Distribution of the Human Blood Groups. Blackwell, Oxford, 221.

Studies on the Caingang Indians

III. BLOOD GROUPS

FRANCISCO M. SALZANO
Departamento de Genética, Instituto de Ciências Naturais, Universidade do Rio Grande do Sul, Pôrto Alegre, Brazil

The study of blood groups can give important insight into micro-evolutionary problems. It has therefore been included in the researches which are being described in this series of papers about the Caingang Indians of Rio Grande do Sul, Brazil.

These Gê-speaking populations have already been studied from the demographic (Salzano, '61a) and genetic-morphologic (Salzano, '61b) point of view. Also a report about their hemoglobin types was published by Tondo and Salzano ('60). The demographic studies showed that Caingang communities in Rio Grande do Sul present a high degree of isolation with high inbreeding coefficients. At least in some loci these conditions are favorable to the occurrence of genetic drift. Besides there exists a local variation in the amount of gene flow between the Indians and their neighboring populations; and the high mortality before the age of reproduction indicates that also selective factors have to be taken into consideration in studying these groups.

To what extent then are the complex interactions between these factors modifying the gene frequencies in regard to blood group systems? This was the main question which determined the study that is now being presented. In addition the collection of new serological data about a South American tribe are of intrinsic interest for racial comparisons.

MATERIAL AND METHODS

The individuals under consideration live in 4 localities in the Northern region of the State of Rio Grande do Sul, Brazil. Details about these places and the populations inhabiting them can be gathered from earlier reports of this series (Salzano, '61a, '61b; Tondo and Salzano, '60).

Two cubic centimeters of blood were collected by venipuncture and placed in sterilized tubes with an anticoagulant (0.2 cc of the following solution: ammonium oxalate: 2.4 g; potassium oxalate: 1.6 g; formalin (40%): 2 cc; distilled water: 200 cc. The liquid portion of this solution was evaporated in an oven and the tubes closed with sterilized rubber corks). These tubes were kept in an ice-box until the arrival to the laboratory which occurred three or four days after the collection. In the laboratory they were placed in the refrigerator until the performance of the tests. These were finished three to seven days after the collection. The method of collection, transport and conservation of the blood seems to have given satisfactory results, since the samples generally arrived in Pôrto Alegre in very good condition. For control reasons in a number of instances the author's blood was collected at the same time the samples were drawn; it always showed the expected reactions according to tests previously performed at the University of Michigan. All tests were made with the appropriate control.

The antisera used were the following: 1. *anti-A* and *anti-B*: Laboratório Paulista de Biologia; Banco de Sangue de São Paulo; Johnson; Pinheiros; Ortho Pharmaceutical Co. 2. *Anti-*A_1: Ortho. 3. *Anti-*A_2 (H): seed extracts of *Ulex europeus* prepared following the method of Boyd and Shapleigh ('54). 4. *anti-M:* Ortho and one of human origin furnished by Dr. F. Ottensooser. 5. *anti-N:* Ortho and seed extracts of *Vicia graminea*, prepared by Dr. F. Ottensooser (Ottensooser, '58). 6. *anti-C* (rh'): Ortho. 7. *anti-c* (hr'): Ortho. 8. *anti-D* (Rho): Ortho; Laboratório Paulista de Biologia; Johnson. 9. *anti-C +D* (rh' + Rho): Johnson. 10. *anti-E* (rh''): Ortho;

Johnson. 11. *anti-e* (hr″): Certified Blood Donor Service, Inc. 12. *anti-Kell:* Knickerbocker Blood Bank. 13. *anti-P:* Knickerbocker Blood Bank. 14. *anti-Diego:* furnished by Dr. Miguel Layrisse. 15. *anti-human globulin:* Johnson; Ortho.

All tests were performed in tubes and in all cases the instructions given by the supplier of each particular serum were followed rigorously. In almost all cases the two anti-N cited were used simultaneously for a mutual control of specificity.

In estimating the various gene frequencies the fact that part of the individuals were related to others tested was taken into account, the "original parents method" by Ceppellini, Siniscalco and Smith ('55) being used for estimating the population frequencies. In relation to the Rh system (results when 4 sera are used) the formulas developed by Mourant ('54) and the standard errors derived by Boyd ('56b) were applied. The standard errors for the frequencies in the other systems were those indicated by Ceppellini et al. (l.c.).

RESULTS

ABO blood groups

The results arrived at for this blood group can be seen in table 1. The last column of these and the following tables always shows the number of genes utilized for the calculation of the respective gene frequency. In this way the reader can have an idea of the degree of selection necessary in order to determine these frequencies through the elimination of genetically related individuals.

Examining table 1, one can see that group O individuals predominated. From the total number of individuals of all localities 94.63% belonged to this group while 4.03% and 1.34% respectively belonged to groups A and B. The gene frequencies were $r = 0.9687$; $p = 0.0219$; and $q = 0.0094$. The differences among localities are not statistically significant.

In table 2 the results here reported are compared to those obtained from other populations of Brazilian Indians. As one sees here 1,837 individuals tested in more than

TABLE 1

ABO blood group phenotype and gene frequency estimates in Caingang communities of Rio Grande do Sul, Brazil

Localities		O	A	B	Total	p[1]	q[1]	r[1]	No. of genes
Guarita	I	97.73	1.13	1.14	88	—	0.0078	0.9922	128
	M	97.06	2.94	—	34	—	—	—	—
Total		97.54	1.64	0.82	122	0.0129	0.0065	0.9806	155
Nonoai	I	98.36	0.82	0.82	122	0.0048	0.0048	0.9904	208
	M	75.00	12.50	12.50	8	—	—	—	—
Total		96.92	1.54	1.54	130	0.0090	0.0090	0.9820	224
Ligeiro	I	98.46	1.54[2]	—	65	0.0104	—	0.9896	97
	M	76.32	18.42[2]	5.26	38	—	—	—	—
Total		90.29	7.77	1.94	103	0.0403	0.0133	0.9464	152
Cacique	I	96.97	3.03[3]	—	66	p′ = 0.0106 p″ = 0.0107	—	0.9787	94
Doble	M	80.77	15.38[4]	3.85	26	—	—	—	—
Total		92.39	6.52	1.09	92	p′ = 0.0176 p″ = 0.0178	0.0088	0.9558	114
All localities	I	97.95	1.47	0.58	341	0.0076	0.0038	0.9886	527
	M	83.96	12.27	3.77	106	—	—	—	—
Total		94.63	4.03	1.34	447	0.0219	0.0094	0.9687	645

I = Indians; M = Mestizos.

[1] Letters commonly used to represent the frequencies of genes I^A, I^B and I^O, respectively.

[2] All A_1.

[3] One A_1 and one A_2.

[4] Three A_1 and one A_2.

TABLE 2

ABO blood group phenotype and gene frequency estimates in several Brazilian Indian populations

Population	Author	No. studied	O	A	B	p^1	q^1	r^1	No. of genes
More than 15 tribes, Brazil	Review in Salzano ('57)	1,837	100.00	—	—	—	—	1.0000	3,674
Caingang, Paraná	Fernandes ('39)	39	94.87	—	5.13	—	0.0260	0.9740	78
Caingang (Indians and Mestizos), Paraná	Fernandes et al. ('57)	76	81.58	5.27	13.16	0.028	0.044	0.928	?
Caingang, Rio Grande do Sul	Present report	341	97.95	1.47	0.58	0.0076	0.0038	0.9886	527

[1] Letters commonly used to represent the frequencies of genes I^A, I^B and I^O, respectively.

15 Brazilian tribes show the exclusive occurrence of blood group O. There is strong evidence, therefore, that any I^A or I^B gene which appears among Brazilian Indians would have been introduced through interbreeding with White or Negro individuals. This is the probable explanation for the small quantities of such genes present in a fraction of Caingang individuals who, morphologically, did not present any sign of hybridization. But the high frequency of the I^o gene observed in the Indian communities of Rio Grande do Sul shows that 200 years of contact with Whites and Negroes were not sufficient to modify in a significant way the gene frequencies of these populations regarding this system. The Caingangs of the State of Paraná, for instance, show to a much larger extent the effect of interbreeding with groups of different ethnic origins.

The MN system

Results regarding this system in Indian populations of Rio Grande do Sul are shown in table 3. The frequency of the *m* gene in all localities is 0.6994 ± 0.0224. The differences among localities are not statistically significant.

In table 4 the data obtained among the Caingang Indians are compared with those observed among other Brazilian Indian populations. The frequencies of the *m* gene varied to a relatively small degree in 6 of the 7 populations listed (from 0.65 to 0.71). The Caiuás, however, show the aberrant frequency of 0.91 (a value which is different in a statistically significant way from the others). New studies among them are needed in order to see if this difference is real or if it was caused by spoiled sera or sampling accident.

The P system

Table 5 shows the results obtained among the Indian communities of Rio Grande do Sul concerning this system. In a total of 243 individuals 49.38% were P_1+, giving a value for the P_1 gene of 0.2504 ± 0.0245. The differences among localities are not statistically significant.

The value obtained among the Caingangs is compared in table 6 to those reported for other South American tribes. There is no difference in frequencies between the two Brazilian populations tested, but some tribes studied by the group of Layrisse in Venezuela present a higher frequency of the P_1 gene. An isolated comparison between the different ethnic groups tested does not show any significant difference, but if the Irapa and Macoíta samples are combined and compared with the Caingangs the difference becomes significant ($X^2 = 4.26$; 1 d.f.; $P < 0.05$). It is interesting to mention that North American tribes generally present high frequencies of P_1. Some Venezuelan tribes, therefore, could be considered as intermediaries between those with high frequencies found in the North and the ones with lower frequencies observed in the South.

TABLE 3

MN blood group phenotype and gene frequency estimates in Caingang communities of Rio Grande do Sul, Brazil

Localities		MM	MN	NN	Total	Gene *m*	No. of genes
Guarita	I	26.83	68.29	4.88	41	0.6316 ±0.0640	60
	M	76.92	23.08	—	13	—	—
Total		38.89	57.41	3.70	54	0.6849 ±0.0548	76
Nonoai	I	66.67	12.12	21.21	33	0.6949 ±0.0600	60
	M	100.00	—	—	1	—	—
Total		67.65	11.76	20.59	34	0.7049 ±0.0583	62
Ligeiro	I	60.00	35.38	4.62	65	0.7851 ±0.0412	100
	M	36.84	52.63	10.53	38	—	—
Total		51.45	41.75	6.80	103	0.7191 ±0.0361	156
Cacique	I	46.97	46.97	6.06	66	0.6646 ±0.0490	98
Doble	M	50.00	46.15	3.85	26	—	—
Total		47.83	46.74	5.43	92	0.6794 ±0.0436	118
All localities	I	50.24	41.95	7.81	205	0.7023 ±0.0265	318
	M	48.72	44.87	6.41	78	—	—
Total		49.82	42.76	7.42	283	0.6994 ±0.0224	412

Tests with anti-N only

		N+	Total	Gene *m*	No. of genes
Nonoai	I	52.63	19	0.6666 ±0.0988	36
	M	50.00	2	—	—
Total		52.38	21	0.6709 ±0.0829	40

I = Indians; M = Mestizos.

TABLE 4

MN blood group phenotype and gene frequency estimates in several Brazilian Indian population

Population	Author	No. studied	MM	MN	NN	Gene *m*
Tucanos, Amazonas	Biocca and Ottensooser ('44)	68	48.53	42.65	8.82	0.6985
Ramkokamekra, Maranhão	Da Silva ('48)	236	39.41	50.85	9.74	0.6483
Caiuás, Mato Grosso	Ottensooser and Pasqualin ('49)	134	79.85	19.40	0.75	0.9091
Carajás, Mato Grosso	Junqueira et al. ('57)	51	56.86	33.34	9.80	0.705
Several, Mato Grosso	Leite, Villela and Vegas ('58)	50	46.00	50.00	4.00	0.7100
Caingang (Indians and Mestizos), Paraná	Fernandes et al. ('57)	76	36.84	47.37	15.79	0.674
Caingang, Rio Grande do Sul	Present report	205	50.24	41.95	7.81	0.7023

TABLE 5

P blood group phenotype and gene frequency estimates in Caingang communities of Rio Grande do Sul, Brazil

Localities		P_1+	Total	Gene P_1	No. of genes
Guarita	I	40.00	35	0.1582 ±0.0539	48
	M	53.85	13	—	—
Total		43.75	48	0.1920 ±0.0520	64
Ligeiro	I	53.85	65	0.2671 ±0.0469	93
	M	63.16	38	—	—
Total		57.28	103	0.3022 ±0.0436	147
Cacique Doble	I	36.36	66	0.2114 ±0.0458	97
	M	61.54	26	—	—
Total		43.48	92	0.2209 ±0.0387	117
All localities	I	43.98	166	0.2215 ±0.0283	238
	M	61.04	77	—	—
Total		49.38	243	0.2504 ±0.0245	328

I = Indians; M = Mestizos.

TABLE 6

P blood group gene frequency estimates in several South American Indian populations

Population	Author	Gene P_1	No. of indiv.
Venezuela			
Irapas	Layrisse, Layrisse and Wilbert ('60a)	0.3190	138
Macoítas	Layrisse, Layrisse and Wilbert ('60a)	0.3398	78
Pariris	Layrisse, Layrisse and Wilbert ('60a)	0.1699	74
Shapárus	Layrisse, Layrisse and Wilbert ('60a)	0.2005	24
Paraujanos	Layrisse, Layrisse and Wilbert ('60b)	0.2929	120
Peru			
Quechuas	Allen ('59)	0.2701	428
Brazil			
Several, Mato Grosso	Pantin and Junqueira ('52)	0.2325	73
Caingangs, Rio Grande do Sul	Present report	0.2215	166

The Rh system

Data concerning this system among the Caingangs are presented in tables 7 and 9. Table 7 shows the almost absolute predominance of D +. From a total of 352 individuals examined only two (0.57%) were D−. Such data agree with those obtained by other investigators. Thus, in 26 populations of South American Indians tested until now regarding this factor, in a total of 4,061 individuals, only 8 were Rh−. They can probably be accounted for as a result of White admixture. The evidence is strong that the Indian population

TABLE 7

Rh blood group phenotype and gene frequency estimates in Caingang communities of Rio Gran do Sul, Brazil. Samples tested with anti-D (Rho) and anti-E (rh")

Localities		D+	Total	Gene *D*	No. of genes	E+	Gene *e*	No. of genes
Guarita	I	100.00	66	1.0000	96	74.24	0.5366 ±0.0548	88
	M	100.00	33	—	—	90.91	—	—
Total		100.00	99	1.0000	122	79.80	0.5184 ±0.0490	115
Nonoai	I	96.36	55	0.8583 ±0.0361	104	76.36	0.4570 ±0.0490	104
	M	100.00	3	—	—	33.33	—	—
Total		96.55	58	0.8603 ±0.0346	110	74.14	0.4728 ±0.0480	110
Ligeiro	I	100.00	65	1.0000	102	55.38	0.6212 ±0.0500	98
	M	100.00	38	—	—	68.42	—	—
Total		100.00	103	1.0000	158	60.19	0.6124 ±0.0412	152
Cacique Doble	I	100.00	66	1.0000	100	46.97	0.6460 ±0.0500	92
	M	100.00	26	—	—	46.15	—	—
Total		100.00	92	1.0000	120	46.74	0.6463 ±0.0458	112
All localities	I	99.21	252	0.9377 ±0.0100	402	62.70	0.5664 ±0.0265	382
	M	100.00	100	—	—	69.00	—	—
Total		99.43	352	0.9457 ±0.0100	510	64.49	0.5703 ±0.0224	489

I = Indians; M = Mestizos.

of South America presented individuals Rh + only before their contact with Whites.

In the beginning of this research only anti-D and anti-E sera were available. The results obtained with this last antiserum are presented in the right hand columns of table 7. Supposing Fisher's theory of genetic determination of this system is correct calculations could be made concerning genes *E* or *e*. Gene *e* appears with a frequency of 0.5703 ± 0.0224 in the total of individuals examined. It is interesting to mention that while the standard errors did not show significant differences among the several estimates of this gene obtained in different populations, the more sensitive chi square test did show significant differences (total population: $X^2 = 9.26$; 3 d.f.; $P < 0.05$; Indians: $X^2 = 8.94$; 3 d.f.; $P < 0.05$). The lowest estimate of *e* was observed in Nonoai and the highest in Cacique Doble. Notice the similarity between the frequencies obtained in Cacique Doble and Ligeiro which clearly depart from those observed in the two other loca ities.

It is difficult to explain the local vari tion thus obtained. As the differences a only a little below the limit of significan they should not receive too much atte tion, however. Therefore the results o tained among the Caingangs were cor bined for comparison with those four among other Brazilian Indian populatio (table 8). The numbers observed amon the Caingangs are close to those arrived by Fernandes et al. ('57), being intermed ate between those found among t Carajás and several tribes of Mato Gros on one hand and the Bororos and Caiu on the other. There are statistically signi cant differences among the frequencies the several tribes ($X^2 = 32.33$; 5 d.f.; P 0.001). Why do tribes geographically close as the Carajás and Caiuás show suc discordant frequencies of *e*? Addition tests in these and other Mato Grosso pop lations are needed to clarify this point.

The phenotypes found when 4 sera are used simultaneously (anti-C, -D, E, -c) are presented in table 9. All the individuals computed there were tested with an anti-e also. As the results obtained, however, showed a systematic deficiency of e + individuals they were not considered. The differences in the frequency of the several phenotypes which could be distinguished in the three populations studied are not statistically significant. The calculation of the frequency of the several gene arrangements ("chromosomes" according to the English group; alleles according to Wiener) was therefore made based on the totality of the phenotypes observed in the three localities (table 10). Only numbers concerning the total population could be obtained. With the results observed among the Indians it was not possible to calculate the frequencies of the gene arrangements following Mourant's ('54) method due to internal inconsistencies in the frequencies of the several genes. Such inconsistencies could be due to non-specific reactions of some sera, lack of genetic equilibrium in relation to these factors or sampling accidents. At present it is difficult to make a decision for any one of these hypothesis.

As can be seen in table 10 there is great divergency in the chromosome frequencies observed in the several South American Indian populations. However, because the number of individuals tested is generally small (with the exception of Reynafarje's, '57 results) one should be cautious in the interpretation of such divergency. The standard errors of the estimates calculated for the Brazilian samples show that the differences observed, which superficially could be considered high, do not reach the limit of statistical significance.

TABLE 8

Rh blood group gene frequency estimates in several Brazilian Indian populations. Samples tested with anti-E (rh")

Population	Author	Gene e	No. examined
Carajás, Mato Grosso	Junqueira et al. ('57)	0.7386[1]	44[1]
Several tribes, Mato Grosso	Pantin and Junqueira ('52)	0.6517	73
Bororos, Mato Grosso	Ottensooser and Pasqualin ('49)	0.4827	103
Caiuás, Mato Grosso	Ottensooser and Pasqualin ('49)	0.4714	135
Caingangs (Indians and Mestizos), Paraná	Fernandes et al. ('57)	0.6513[1]	33[1]
Caingangs, Rio Grande do Sul	Present report	0.5664[2]	252[2]

[1] Unrelated individuals only.

[2] Number of genes in which this estimate was based: 489 (Method of Ceppellini et al., '55).

TABLE 9

Rh blood group phenotype estimates in several Caingang communities of Rio Grande do Sul, Brazil. Samples tested with anti-C (rh'), anti-D (Rho), anti-E (rh") and anti-c (hr')

Localities		CCDE	CCDee	CcDE	CcDee	ccDE	ccDee	Total
Guarita	I	5.71	28.57	54.29	2.86	8.57	—	35
	M	7.69	15.39	38.46	—	38.46	—	13
Total		6.25	25.00	50.00	2.08	16.67	—	48
Ligeiro	I	6.15	32.31	27.70	10.77	21.53	1.54	65
	M	2.63	23.69	21.05	—	44.74	7.89	38
Total		4.85	29.13	25.24	6.80	30.10	3.88	103
Cacique Doble	I	7.57	50.00	30.31	3.03	9.09	—	66
	M	—	42.31	38.46	11.54	7.69	—	26
Total		5.43	47.83	32.61	5.43	8.70	—	92
All localities	I	6.62	38.55	33.74	4.82	14.46	1.81	166
	M	2.60	28.57	29.86	3.90	31.17	3.90	77
Total		5.35	35.39	32.51	4.53	19.75	2.47	243

I = Indians; M = Mestizos.

TABLE 10

Rh blood group chromosome (or gene) frequency estimates in several South American Indian populations. Samples tested with anti-C (rh′), anti-D (Rho), anti-E (rh″) and anti-c (hr′)

Population	Author	R_z CDE	R_1 CDe	R_2 cDE	R_0 cDe	r cde	No. of indiv.
Venezuela							
Pariris (Carib)	Nuñez Montiel and Nuñez Montiel ('57)	0.0444	0.7899	0.1657	—	—	125
Warrau, Guayo	Layrisse, Arends and Wilbert ('58)	0.0179	0.6758	0.3063	—	—	81
Warrau, Winikina	Layrisse, Arends and Wilbert ('58)	0.0789	0.6662	0.2549	—	—	72
Guayqueri Mestizos	Layrisse, Wilbert and Arends ('58)	0.0157	0.4453	0.1451	0.1155	0.2784	103
Goajiros	Nuñez Montiel, Perez and Nuñez Montiel ('57)	—	0.6107	0.2971	0.0922	—	118
Irapas	Nuñez Montiel, Perez and Nuñez Montiel ('57)	0.0374	0.6451	0.2387	0.0788	—	161
Peru							
Quechuas	Reynafarje ('57)	0.1022	0.3588	0.4165	0.0871	0.0354	800
Chile							
Mapuches	Sandoval and Henckel ('54)	0.0112	0.6322	0.2386	0.1180	—	258
Brazil							
Several tribes, Mato Grosso	Pantin and Junqueira ('52)	0.0511 ± 0.0224	0.5859 ± 0.0949	0.2973 ± 0.1269	0.0657 ± 0.0825	—	73
Caingang (Indians and Mestizos), Paraná[1]	Fernandes et al. ('57)	0.023 ± 0.017	0.496 ± 0.056	0.299 ± 0.051	0.181 ± 0.038	—	76
Caingang (Indians and Mestizos), Rio Grande do Sul	Present report	0.0563 ± 0.0173	0.3439 ± 0.0728	0.5286 ± 0.0640	0.0712 ± 0.0548	—	243

---

[1] Several samples tested with anti-e also.

The Kell system

Chown and Lewis in an article published 1957 expressed the point of view that e presence of the antigen Kell in the lood of any population of North American ndians or Eskimos would indicate the resence of genes of the White race. In e same article they could demonstrate hat many of the K + found previously by atson, Koch and Levine ('54) among the hippewa of Minnesota could be attributed technical errors and the confirmed cases racial admixture.

At the time this research was started two eports, however, had already appeared resenting a frequency of about 20% of ell positives among Brazilian Indians. hey could indicate a significant difference etween South and North American Inians and it was therefore thought to be esirable to have new data about this sysem among the first. Having obtained Kell ntisera for the tests they were used among he Caingang Indians. The results obtained an be seen in table 11. Of 243 individuals tudied only 1 (0.41%) was Kell positive. e had been classified before the tests, owever, as Mestizo.

In table 12 the results observed among he Caingang are compared to those obained in other South American tribes. Not onsidering the papers of Pantin and Junqueira ('52) and Junqueira et al. ('57), only 4 of the 1,105 individuals studied proved to be K +. It is therefore possible that the results obtained by the authors of the above-mentioned papers were due to some undetected technical problem (non-specific sera?). Racial admixture cannot explain the difference since the Indians under consideration have not had sufficient contact with Whites to change gene frequencies in such a significant way.

The Diego system

Since the first report about this system (Levine et al., '54) a great amount of investigation has been carried out regarding its frequency in different populations. This was to a great extent due to Dr. Miguel Layrisse who generously furnished antisera for these tests to laboratories all over the world. At the time this investigation was started there was already a sample of Caingang Indians tested with regard to this factor (Fernandes et al., '57). Individuals of this tribe living in Palmas, Paraná, showed a very high frequency of Di(a +), as a matter of fact the highest reported at the time. Obviously a confirmation of this high frequency in other Caingang populations was highly desirable; therefore a letter was written to Dr. Layrisse asking for antisera

TABLE 11

Kell blood group phenotype and gene frequency estimates in Caingang communities of Rio Grande do Sul, Brazil

Localities		K–	Total	Gene *k*	No. of genes
Guarita	I	100.00	35	1.0000	50
	M	100.00	13	—	—
Total		100.00	48	1.0000	66
Ligeiro	I	100.00	65	1.0000	102
	M	97.37	38	—	—
Total		9.03	103	0.9935 ± 0.0063	158
Cacique Doble	I	100.00	66	1.0000	100
	M	100.00	26	—	—
Total		100.00	92	1.0000	120
All localities	I	100.00	166	1.0000	252
	M	98.70	77	—	—
Total		99.59	243	0.9971 ± 0.0028	344

I = Indians; M = Mestizos.

TABLE 12

Kell blood group phenotype and gene frequency estimates in several South American Indian populations

Population	Author	K+	Gene *K*	No. o indiv
Venezuela				
Irapas	Nuñez Montiel, Perez and Nuñez Montiel ('57)	1.96	0.0098	153
Irapas	Layrisse, Layrisse and Wilbert ('60a)	Zero	Zero	138
Macoítas	Layrisse, Layrisse and Wilbert ('60a)	Zero	Zero	78
Pariris	Layrisse, Layrisse and Wilbert ('60a)	Zero	Zero	74
Shapáru	Layrisse, Layrisse and Wilbert ('60a)	Zero	Zero	24
Paraujanos	Layrisse, Layrisse and Wilbert ('60b)	0.83	0.0042	120
Peru				
Quechuas	Allen ('59)	Zero	Zero	302
Brazil				
Several tribes, Mato Grosso	Pantin and Junqueira ('52)	23.29	0.1242	73
Carajás, Mato Grosso	Junqueira et al. ('57)	20.00	0.116	35
Caingang (Indians and Mestizos), Paraná	Fernandes et al. ('57)	Zero	Zero	50
Caingang, Rio Grande do Sul	Present report	Zero	Zero	166

TABLE 13

Diego blood group phenotype and gene frequency estimates in Caingang communities of Rio Grande do Sul, Brazil

Localities		Di(a+)	Total	Gene Di^a	No. of genes
Guarita	I	32.69	52	0.1623 ± 0.0400	90
	M	33.33	21	—	—
Total		32.88	73	0.1509 ± 0.0346	112
Nonoai	I	14.85	101	0.0727 ± 0.0200	174
	M	16.67	6	—	—
Total		14.95	107	0.0732 ± 0.0200	188
Ligeiro	I	32.31	65	0.1698 ± 0.0387	98
	M	27.78	36	—	—
Total		30.69	101	0.1436 ± 0.0283	150
Cacique Doble	I	48.72	39	0.2844 ± 0.0608	60
	M	54.55	11	—	—
Total		50.00	50	0.2712 ± 0.0566	66
All localities	I	28.02	257	—	—
	M	32.43	74	—	—
Total		29.00	331	—	—

I = Indians; M = Mestizos.

or the study. The antisera were furnished nd the tests made. The results can be seen n table 13. The frequency of Di (a +) found was 29.00% in 331 individuals. But there xists a great variability in the frequency f carriers of this antigen in the different ocalities studied. While Nonoai presented nly 14.95% of Diego positives, in Cacique Doble this frequency reached 50.00%! The frequency of the Di^a gene varied in the ame way from 0.0732 to 0.2712. These ifferences are statistically significant (to-al population: $X^2 = 16.85$; 3 d.f.; $P <$ .001; Indians: $X^2 = 17.54$; 3 d.f.; $P <$ .001).

It is difficult to decide if this variation epresents real differences or not. The more discordant frequencies were found in Nonoai and Cacique Doble. At the time Nonoai individuals were sampled no positive controls could be used (because no eep freezer was available to keep the positive bloods in glycerin); it is therefore possible that some false negatives exist among these specific samples (in all other cases, however, positive controls were used). On the other hand, the reactions obtained with one anti-human globulin obtained from Ortho Parmaceutical Co. always proved not to be very strong, the opposite being true of two other globulins of Johnson and Johnson of Brazil utilized for the tests with bloods from Cacique Doble. These technical difficulties indicate that one should be cautious in interpreting these differences. New studies are being planned in these populations in order to find a solution for this problem.

In table 14 the data reported here for the Indian fraction without signs of hybridization is compared to those collected by several investigators in populations of South American Indians. The figures are quite variable. Frequencies from zero to 35.54% of Di(a +), for instance, were reported for different Venezuelan tribes. Even with-

TABLE 14

Diego blood group phenotype and gene frequency estimates in several South American Indian populations

Population	Author	Di(a+)	Gene Di^a	No. studied
Venezuela				
19 Indian populations	Review in Layrisse and Wilbert ('60)	0–35.54	0–0.1971	1535
Dutch Guiana				
Several	Nijenhuis (personal communication to Layrisse and Wilbert, '60)	16.44	0.0859	73
Colombia				
Tunebo (Chibcha)	Layrisse, Layrisse and Wilbert (unpublished)	1.00	0.0050	100
Peru				
Quechua	Allen ('59)	24.03	0.1284	308
Quechua	Layrisse, Best and Bermejo (unpublished)	3.36	0.0170	119
Aimara	Layrisse, Best and Bermejo (unpublished)	17.24	0.0903	58
Argentina				
Quechua	Scaro ('58)	2.70	0.0136	74
Chile				
Araucanos	Meza Arrau, Stading and Nijamkin ('58)	4.00	0.0213	100
Brazil				
Several, Mato Grosso	Leite, Villela and Vegas ('58)	14.58	0.0758	48
Carajás, Mato Grosso	Junqueira-et al. ('57)	36.11	0.208	36
Caingangs (Indians and Mestizos), Paraná	Fernandes et al. ('57)	45.83	0.279	48
Caingangs, Rio Grande do Sul	Present report	14.85–48.72	0.0727–0.2844	257

in one single ethnic group, the Quechuas of Peru, frequencies as different as 3.36% and 24.03% of Di(a +) were found. The first figure is more in accordance with the 2.70% of Di(a +) obtained by Scaro ('58) among the Quechuas of Argentina.

DISCUSSION

According to the observations above the question posed in the introduction can now be discussed. In what way can the blood group frequencies observed throw light upon the evolutionary factors active in these populations?

Data collected among these groups and to be reported elsewhere (Salzano, '61a) have shown that gene flow is occurring with different intensities between the Caingang and neighboring White and Negro populations. Despite this fact the high frequencies of the I^o, D, m and k genes observed show that the changes occurred in the original frequencies prevailing before the contact with Whites and Negroes were not very pronounced. But there is no doubt that this factor is altering the gene frequencies of these populations. This can be clearly demonstrated through the strong parallel which exists between the quantity of Mestizos present in the several localities and the gradual lowering of gene I^o frequencies. Thus (Salzano, '61a) the locality which presents the largest number of Indians without signs of hybridization is Nonoai, followed by Guarita, Cacique Doble and Ligeiro, while the frequencies of the I^o gene in these communities show exactly the same cline (Nonoai: 0.9820; Guarita: 0.9806; Cacique Doble: 0.9558; and Ligeiro 0.9464 — see table 1).

In only two of the six blood group systems tested significant differences were found among the different localities under observation. They concern the frequencies of genes e and Di^a. A more detailed discussion of the causes of such variation will be presented in a forthcoming paper, in which they will be considered in the light of other results obtained among these populations (Salzano, '61d). The technical difficulties experienced with the Diego system were already stressed. It should be pointed out, however, that large differences seem to exist in the frequency of gene Di^a among South American Indian populations. Layrisse and Wilbert ('60) tried to expla
them mainly on the basis of migratic
and gene flow. However, since there a
proven instances of *erythroblastosis f*
talis due to this factor (its discovery
curred in the course of studies of the seru
of a woman immunized by incompatibil
in this system) it would be worthwhile
consider selection as a factor conditioni
this diversity. This could be verified in t
Mestizo populations of South Ameri
Pacific Coast through: (a) the frequen
with which *erythroblastosis foetalis* due
the Diego factor occurs in comparison wi
those due to other factors; and (b) stu
of marriages between Di(a +) men a
Di(a −) women to verify if there is
excess of abortions and stillbirths amo
them when compared to other types
marriages.

As was mentioned in the introducti
the collection of new serological data in
South American tribe has intrinsic intere
for racial comparisons. A problem whic
for instance, has been widely discuss
among physical anthropologists is the que
tion if the North and South American I
dians should be considered one race or
or separated into two different ethr
groups. Of the 10 racial morphologic
classifications cited by Comas ('57)
least 4 considered American Indians
single race. Boyd ('50, '56a), based upo
blood group results, includes the North ar
South American Indians plus the Eskim
in one group only (the American India
Race). The author was able to show son
time ago, however, (Salzano, '57), an ev
dent heterogeneity even within the Sout
American Indians. For them the variabili
present in relation to the ABO blood grou
showed a very interesting parallel with th
distribution of 4 of the ethnic groups pr
posed by Imbelloni ('38, '57) in his class
fication of Indians of this region. If, a
was shown in the above-mentioned articl
there exist significant variability betwee
the South American Indians they shoul
not be classified as one group only an
certainly should they not be combined wit
the North American Indians and Eskimo

The data obtained among the Caingan
are perfectly in accordance with this poi
of view. There are differences in the fre
quency of the gene which condition the R

(results with 4 sera) and the P system among the Caingang and other South American Indian populations; plus different frequencies between the tribe here under consideration and North American tribes in relation to the MN, P and ABO blood groups. Similar differences were found by the author in other genetic systems which condition morphological variants (Salzano, '61b) and color blindness (Salzano, '61d). All these data show that the simplified concept of an "American Indian Race" should be abandoned since it leads to a false idea of homogeneity which does not exist.

SUMMARY

The study of 6 blood group systems in 447 Caingang Indians and Mestizos distributed over 4 localities in the State of Rio Grande do Sul, Brazil shows that:

(a) the frequency of the majority of the genes studied does not present significant differences among localities; but such differences do exist in relation to the *e* gene of the Rh system and Di^a of the Diego system;

(b) the high frequencies and in some cases absolute predominance of genes I^o, *D*, *m* and *k* suggest that the hybridization process which is occurring in these populations has not greatly modified the gene frequencies present among them before the contact with Whites and Negroes;

(c) the frequencies of the genes which condition the MN, P and Rh (4 sera) systems are similar to those observed in other populations of Brazilian Indians but differ in some cases from those present in South American (systems P and Rh) and North American Indians (systems MN, P and Rh).

(d) no Kell positives were found among Indians without signs of hybridization. This is in accordance with the thesis of Chown and Lewis ('57) who say that this antigen is not present in American Indian populations free of White admixture.

ACKNOWLEDGMENTS

Thanks are due to Dr. Miguel Layrisse who provided the anti-Diego serum and to Professor Alarich R. Schultz who helped in the collection and identification of *Ulex europeus* from whose seeds anti-H extracts were made. Mr. Girley V. Simoes helped in the collection and analysis of the data. This work has been supported in part by funds from the Rockefeller Foundation and the Comissão de Pesquisas of the University of Rio Grande do Sul.

LITERATURE CITED

Allen, F. H. 1959 Summary of blood group phenotypes in some aboriginal Americans. Am. J. Phys. Anthrop., *17:* 86.

Biocca, E., and F. Ottensooser 1944 Estudos etno-biológicos sôbre os índios da região do Alto Rio Negro — Amazonas. I. Grupos sanguíneos comuns e fatores M e N. Arq. de Biol., *28:* 1–8.

Boyd, W. C. 1950 Genetics and the Races of Man. Little, Brown and Co., Boston.

——— 1956a Anthropologie und Blutgruppen. Klin. Wochenschrift, *34:* 993–999.

——— 1956b Variances of gene frequency estimates. Am. J. Hum. Genet., *8:* 24–38.

Boyd, W. C., and E. Shapleigh 1954 Diagnosis of subgroups of blood groups A and AB by use of plant agglutinins (lectins). Jour. Lab. Clin. Med., *44:* 235–237.

Ceppellini, R., M. Siniscalco and C. A. B. Smith 1955 The estimation of gene frequencies in a random-mating population. Ann. Hum. Genet., *20:* 97–115.

Chown, B., and M. Lewis 1957 The Kell antigen in American Indians. Am. J. Phys. Anthrop., *15:* 149–156.

Comas, J. 1957 Manual de Antropología Física. Fondo de Cultura Economica, México.

Da Silva, E. M. 1948 Grupos sanguíneos comuns e fatores M e N em índios Canella (Rankokamekra) do Maranhão. Rev. Museu Paul., *2:* 271–274.

Fernandes, J. L. 1939 Notas hemato-antropológicas sôbre os Caingangues de Palmas. Rev. Med. Paraná, *8:* 1–8.

Fernandes, J. L., P. C. Junqueira, H. Kalmus, F. Ottensooser, R. Pasqualin and P. Wishart 1957 P. T. C. thresholds, colour vision and blood factors of Brazilian Indians. I. — Kaingangs. Ann. Hum. Genet., *22:* 16–21.

Imbelloni, J. 1938 Tabla clasificatória de los Indios. Regiones biológicas y grupos raciales humanos de America. Physis, *12:* 229–249.

——— 1957 *In* Biasutti, R. Le razze e i popoli della terra. 2nd edition. Unione Tipografico-Editrice Torinese, Torino.

Junqueira, P. C., H. Kalmus and P. Wishart 1957 P. T. C. thresholds, colour vision and blood factors of Brazilian Indians. II. — Carajás. Ann. Hum. Genet., *22:* 22–25.

Layrisse, M., T. Arends and J. Wilbert 1958 Peculiar distribution of the Diego factor among the Warrau. Nature, *181:* 118–119.

Layrisse, M., Z. Layrisse and J. Wilbert 1960a Blood group antigen tests of the Yupa Indians of Venezuela. Amer. Anthrop., *62:* 418–436.

——— 1960b Blood group antigens among the Paraujano. Am. J. Phys. Anthrop., *18:* 131–139.

Layrisse, M., and J. Wilbert 1960 El antígeno del sistema sanguíneo Diego. Editorial Sucre, Caracas.

Layrisse, M., J. Wilbert and T. Arends 1958 Frequency of blood group antigens in the descendants of Guayqueri Indians. Am. J. Phys. Anthrop., *16:* 307–318.

Leite, G. M., M. O. Villela and V. S. Vegas 1958 A distribuição de alguns fatores de grupos sanguíneos em índios brasileiros do Alto Xingu. Rev. Paul. Med., *53:* 370–372.

Levine, P., E. A. Koch, R. T. McGee and G. H. Hill 1954 Rare human isoagglutinins and their identification. Am. J. Clin. Pathol., *24:* 292–304.

Matson, G. A., E. A. Koch and P. Levine 1954 A study of the hereditary blood factors among the Chippewa Indians of Minnesota. Am. J. Phys. Anthrop., *12:* 413–426.

Meza Arrau, C., J. Stading and A. Nijamkin 1958 Investigación del "sistema Diego" en la población chilena en general y especialmente en los indios Mapuches. Sangre, *3:* 360. Cited by Layrisse and Wilbert, 1960.

Mourant, A. E. 1954 The distribution of the human blood groups. Charles C Thomas, Springfield.

Nuñez Montiel, J. T., and A. E. Nuñez Montiel 1957 El factor Diego y otros sistemas Rh-Hr, ABO, MN en los indios Rionegrinos. Acta Cient. Venezol., *8:* 134–136.

Nuñez Montiel, J. T., R. A. Perez and A. Nuñez Montiel 1957 Estudio hematológico en grupos indígenas del Estado Zulia. Sistemas ABO, MN, Rh, Duffy, Kell and Diego. Acta Cient. Venezol., *8:* 10–13.

Ottensooser, F. 1958 Anti-N vegetal: origem preparo, contrôle. Anais Acad. Bras. Cienc *30:* 65–73.

Ottensooser, F., and R. Pasqualin 1949 Bloo types of Brazilian Indians (Mato Grosso). Am J. Hum. Genet., *1:* 141–155.

Pantin, A. M., P. C. Junqueira 1952 Bloo groups of Brazilian Indians. Am. J. Phy Anthrop., *10:* 395–405.

Reynafarje, C. 1957 El factor Rh y otros grupo sanguíneos en los índios peruanos. Anale Facultad Med., Lima, *40:* 573–584.

Salzano, F. M. 1957 The blood groups of Sout American Indians. Am. J. Phys. Anthrop., *15* 555–579.

——— 1961a Studies on the Caingang In dians. I. — Demography. Human Biology, 33 110–130.

——— 1961b Studies on the Caingang Indian II. — Morphological characteristics. Zeitschrif für Morphologie und Antropologie, *51:* 356–371

——— 1961d Rare genetic conditions amon the Caingang Indians. Ann. Hum. Genet., 25 123–130.

Sandoval, L., and C. Henckel 1954 The ABC MNS and Rh — Hr blood groups of the Ma puche Indians of Cautin Province, Chile, Hum Biol., *26:* 324–329.

Scaro, J. L. 1958 Investigación del factor Dieg en aborígenes de la Quebrada de Humahuaca Rev. Soc. Argent. Biol., *34:* 71–74.

Tondo, C. V., and F. M. Salzano 1960 Hemo globin types of the Caingang Indians of Brazil Science, *132:* 1893–1894.

SHERWOOD L. WASHBURN

Viking Fund Medalist
for 1960

SHERWOOD L. WASHBURN

Viking Fund Medalist for 1960

Dr. Sherwood L. Washburn has been chosen as the recipient of the 1960 Viking Fund Medal and Award in Physical Anthropology. The selection was made by a seven-man committee of the American Association of Physical Anthropologists, all of whom are themselves previous recipients of the same award.

Dr. Washburn was born in Cambridge, Mass., on November 26, 1911 and graduated from Groton in 1931. He received his B.A. degree from Harvard in 1935 and his Ph.D. in Anthropology there in 1940. His graduate work was done in the department which was then directed by the late Professor Earnest A. Hooton. Dr. Washburn, therefore, shares with a number of other leading American physical anthropologists the great good fortune of having come under the influence of that very stimulating teacher and investigator.

Dr. Washburn served, first as an instructor and then later as an assistant professor of anatomy, at the College of Physicians and Surgeons of Columbia University, during the period from 1939 to 1947. He then joined the faculty of the University of Chicago as associate professor in the Department of Anthropology, where he was subsequently promoted to a full professorship. Since 1958, he has been Professor of Anthropology at the University of California at Berkeley.

Dr. Washburn was selected as the recipient of the 1960 Viking Fund Award in recognition of his important contributions to the field of Physical Anthropology. Especially, noteworthy among these are his numerous studies of the developing and the adult skeleton of man and of various animals, his pioneering attempts to modify experimentally the adult form of various skeletal parts, and his well documented field observations on the social behavior of baboons, which he undertook in an attempt to obtain additional information that could be useful in the further elucidation of the evolution of human behavior — a topic which is now Dr. Washburn's principal research interest.

William Walter Greulich, *President*
American Association of Physical Anthropologists

CURRICULUM VITAE —
DR. SHERWOOD L. WASHBURN

Born: Cambridge, Massachusetts, November 26, 1911.

Educated: Groton School 1931; B.A. Harvard 1935, Ph.D. 1940.

Present Position: Professor of Anthropology, University of California at Berkeley.

Positions Held: Instructor, Assistant Professor of Anatomy, Columbia University, 1939–47; Associate Professor, Professor of Anthropology, University of Chicago, 1947–58; Professor of Anthropology, University of California, '58–; Chairman of Department, '61–. Research Associate, Wenner-Gren Foundation for Anthropological Research; Fellow, Center for Advanced Study in the Behavioral Sciences.

Member of: American Anthropological Association (President-Elect 1961 to become President 1962); American Association of Physical Anthropologists (President 1951–52); American Association of Anatomists.

Editor of: *American Journal of Physical Anthropology,* 1955–57; *Viking Fund Publications in Anthropology,* 1956–59.

Field Work: in Siam and Borneo, Uganda, the Rhodesias, Kenya.

Book Reviews

THE EVOLUTION OF MAN. By G. W. Lasker. Pp. XVI + 239. $3.50. Holt, Rinehart and Winston, Inc., 1961.

To many concerned with teaching physical anthropology at a very elementary level and seeking a text from which to work, Dr. Lasker's book will be welcome. It introduces a variety of topics, today all regarded as legitimate fields of anthropological investigation, and endeavors with moderate success to show how, diverse though they be, they are all related to a central theme, human evolution past and present. About half the book is devoted to man's biological past, as inferred from primate studies and demonstrated by the fossil record, and is essentially descriptive. The remainder, developing from a chapter on elementary genetics, discusses the processes by which evolution is brought about, and leads to a brief review of races, plasticity and growth.

There are criticisms. The book is not well balanced; far too many pages (over one quarter of the whole) are claimed by the fossil descriptions — material which is readily accessible in many another elementary text — and far too few by the fields in which Lasker's own particular interests have lain. It is not immediately clear that what appears to be a somewhat (p. 1) unwieldy formal definition "physical anthropology is the study of man's evolution and biological variation, and encompasses the study of manlike fossils and fossil man" is in fact only the first part of an extended definition by content. Among recent trends (p. 3) increased attention to experimental procedures during the last two decades is surely of sufficient importance to merit mention. The impression is given that it is molecular size that determines speed of migration in electrophoresis (p. 162); that the initial generation of entirely Rh+ individuals in a small population where Rh— were also present previously represents fixation (p. 174). Race differences are attributed mainly to drift rather than to selection (p. 173 et seq.); Lasker is perhaps rightly cautious in saying that the arguments that race differences are adaptive are "interesting, even plausible" though for the most part as yet "undemonstrated"; yet one wonders how far this assessment is colored by omission of adequate reference to the increasing body of experimental work noted above.

However, the most important criticism is that there is insufficient material in the book. Admittedly the appetite is whetted, but the one or two references at the end of the sections are not enough to allow the reader to follow up the various topics touched on. Whether this is a criticism of the book or of the methods of teaching for which it is designed, is not clear. One is left with the impression that the reader may perhaps acquire the names of a number of topics rather than their content.

D. F. Roberts
Oxford University

GENETICS AND TWENTIETH CENTURY DARWINISM, *Cold Spring Harbor Symposia on Quantitative Biology, Vol. XXIV; The Biological Laboratory, Cold Spring Harbor, L. I., New York, 1959, 321 pages.*

This Cold Spring Harbor Symposium honors the centenary of the publication of Darwin's treatise, *Origin of Species.* Appropriately, emphasis is upon evolutionary problems related to genetics.

The program was planned by Theodosius Dobzhansky with the assistance of Carleton S. Coon, G. Ledyard Stebbins, and Bruce Wallace. All of the separate sections, "Theory of the Gene and Raw Materials of Evolution," "Natural Selection and Race Formation," "Ecological Systems and Social Organizations," "Isolating Mechanisms and Speciation," "Fossil Record and Rates of Evolution," and "Trends of Evolution," are of the high quality which has come to be expected of the Cold Spring Harbor Symposia. The seven papers which deal entirely, or in part, with human evolution are for the greater part descriptive, contrasting in an informative way with the predominantly analytical and interpretative papers which make up the remainder of this Symposium. It would be quite impossible to do full justice to so impressive a volume in a short review. Therefore, I will take a single topic of interest to the physical anthropologist which cuts across several of the papers of the Symposium which do not deal specifically with man, and that will illustrate the possible rewards to be gained from a careful study of this volume in its entirety.

In the introductory address, "Where Are We?," Ernst Mayr eloquently verbalizes a simple fact close to the heart of the physical anthropologist, "What is exposed to natural selection is not the individual gene nor the genotype but rather the phenotype, the product of the interactions of all genes with each other and with the environment." The genetic meaning of this statement is that natural selection must operate simultaneously on a large number of loci, resulting in the accumulation of those genes which produce maximal viability in their allelic and epistatic interactions. This is in brief, and in the most simple terms, the basis for Dobzhansky's "balance hypothesis" and Lerner's "genetic homeostasis." Mayr selects as an example of the thesis which he develops " —— the conservative nature of the frequencies of blood group genes in human races. Even though individual blood groups genes and genotypes differ in their selective values under different conditions quite drastically from each other (particularly at the ABO locus), the relative frequency of the genes remains relatively stationary in a given population apparently owing to various balance mechanisms (allelic and epistatic)." The kind of genes which exist, and the type of balance mechanism which pertain will relate to the nature of the population. "There is every reason to believe that the internal genetic structure of an open population is quite different from that of a closed one. The relative importance of most genetic processes, such as mutation, random fixation, inbreeding, heterosis, and others will be entirely different in the two types of populations." (Mayr).

In a stimulating paper entitled, "Geneti
Conditions Which Promote or Retard th
Formation of Species," H. L. Carson pr
sents a provocative hypothesis concernin
the relative importance of the heter
zygous and homozygous state in respec
to selection. "Under conditions where
race is being formed, as for example, i
ecologically marginal populations of
polytypic species, it is suggested that na
ural selection tends to favor the hom
zygous rather than the heterozygous stat
at the majority of loci. They tend to b
homozygous genetically and for chrom
somal aberrations to be phenotypicall
uniform and to be closely adapted to
limited set of environmental niches. The
show relatively little developmental buffe
ing against changes in the environment
At the ecological margin of a species rang
the population size may be expected to b
relatively small: "Small populations, it i
contended, can ill afford the luxury o
balanced polymorphism because of the e
pense of the continual production of les
fit homozygotes." This interesting hypoth
esis is further elaborated by Carson an
has many theoretical possibilities for th
human problem, particularly as it co
trasts ecologically marginal populations t
the central or main population of th
species. On the basis of the argument pr
sented, Carson then suggests that: "Ma
ginal populations represent the growin
points, thus the main source of new ev
lutionary change. Central population
given over to adjustment through heter
sis, become progressively less able to pr
liferate new entities. Thus does the popu
lation pass from the reproductive phas
to one of senescence, characterized by
high degree of heterozygous balance wit
reduced free recombination."

In a second paper, "Influence of Geneti
Systems on Geographical Distribution
Bruce Wallace considers one aspect o
marginal populations in respect to evolu
tionary processes. In this paper adapta
tion of boundary populations to local en
vironmental conditions are analyzed i
respect to the possible disruptive effe
gene flow from the interior or bulk of th
species range will have upon gene comb

nations which are adaptive at the population boundary. Experimental data are cited to contrast events taking place within the species to events occurring at the margin. Several possible alternative explanations are discussed in respect to the examples cited. Direct extension to the human problem will not be attempted but rather a generalization put forth, which, together with Carson's hypothesis, may indicate some interesting possibilities for interpreting the anthropologist's descriptive data on marginal groups in man. Genetic changes which arise at the species margin stand in multiple relationships to the adaptive and evolutionary history of the species, their importance depending, perhaps, most importantly, upon the direction or amount of gene flow, and the degree to which these changes are coadaptive with the gene pool of the rest of the population.

If man's genetic response to his environment differs markedly between marginal (relatively closed) and central (open) populations, and also depends upon the degree and nature of the gene flow between the marginal group and the bulk of the population, such marginal groups may be far more interesting than mere cultural and morphological relics from which to speculate upon man's historical stratifications. Some may represent relatively rapid human evolution and provide valuable examples for the study of man's genetic adaptation to very specific environmental forces.

There is much in this Symposium which, with careful study, could help the physical anthropologist find his way to an exciting interpretation of the processes of human evolution, and away from the now sterile tradition, however colorful, of merely describing its consequences.

RICHARD H. OSBORNE
Sloan-Kettering Institute
(410 E. 68th St., New York City)

Index

A

A note on the fusion of the lunate and triquetral centers 251
A photographic method for craniometrics 245
Acheson, Roy M. See Hewitt, David 321
Adolescence, some aspects of skeletal development through
  I. Variations in the rate and pattern of skeletal maturation at puberty 321
  II. The inter-relationship between skeletal maturation and growth at puberty 333
Adolescence, size and form of the dental arches in children with good occlusion studied longitudinally from age 9 years to late 263
Age and sex of the Indian Knoll skeletal population: demographic and methodological aspects 237
Alexander, Milton, Robert S. Zeigen and Irvin Emanuel. Anthropometric data presented in three-dimensional forms 147
Ancestry, compared with college men and women of the Untied States and England, physiques of Hawaii-born young men and women of Japanese 173
Ancestry, stature and build of Hawaii-born youth of Japanese 159
Anthropologist, manned space flight vehicles and the physical 185
Anthropometric data presented in three-dimensional forms 147
Anthropometric findings on migrant and non-migrant Mexicans, age, environment and migration: Further 203
Anthropometric observations, the western Apache: some 227
Antigens in Goajiro Indians, the blood group 255
Aoki, Tsuyoshi. See Yasuda, Kenjiro 23
Apfelbaum, Benjamin. See Garn, Stanley M. 365
Arches, dental in children with good occlusion studied longitudinally from age 9 years to late adolescence 263
Association between alternate sequences of hand-wrist ossification 361
Avis, Virginia. The significance of the angle of the mandible: an experimental and comparative study 55

B

Bergkvist, B. See Lewin, T. 245
Blood group antigens in Goajiro Indians 255
Blood groups of Chimpanzees: The Rh-Hr (CDE/cde) blood types, the 35
Blood groups of Sainis of Punjab, the study of ABO 223
Blood vessels of the heart of the Gorilla Gorilla beringei, the 373
Blood groups of the Kutchin Indians at Old Crow, Yukon Territory 383
Blood groups, studies on the Caingang Indians. III 391
Blumberg, B. S., Elizabeth W. Ikin and A. E. Mourant. The blood groups of the Pastoral Fulani of Northern Nigeria and Yoruba of Western Nigeria 195
Bones of the foot in relation to morphology, radiological studies of variation in ossification of the foot. IV. The length and growth of 137
Book Reviews:
  The face: in five dimensions. By Viken Sassouni 85
  Radiation, genes, and man. By Bruce Wallace and Th. Dobzhansky 87
  An odontometrical study on the Norwegian Lapps. By Reider Selmer-Olsen 88
  The antecedents of man. By W. E. Le Gros Clark 88
  Genetic basis of morphological variation. By R. H. Osborne and F. V. De George 213
  The processes of ongoing human evolution. By Gabriel Ward Lasker 215
  Natural selection in human populations. By D. F. Roberts and G. A. Harrison 215
  Nature and man's fate. By Garrett Hardin 217
  Behavior and evolution. By Anne Roe and George G. Simpson 218
  The dentition of the australopithecinae. By John T. Robinson 219
  Human biochemical genetics. By H. Harris 220
  The evolution of man. By G. W. Lasker 409
  Genetics and twentieth Century Darwinism. Cold Spring Harbor Symposia on Quantitative Biology, Vol. XXIV 409
Brain volume, the correlation between external cranial volume and 317
Bushbaby (*Galago senegalensis*), the skin of primates. IV. The skin of the lesser 23

C

Caucasoid males, the distribution of chest hair in 285
Chagula, W. K. The liver of the mountain Gorilla (*Gorilla gorilla beringei*) 309
Chan, S. T., K. S. F. Chang and F. K. Hsu. Growth and skeletal maturation of Chinese children in Hong Kong 289
Chang, K. S. F. See Chan, S. T. 289
Chest hair in Caucasoid males, the distribution of 285
Chimpanzees: The Rh-Hr (CDE/cde) blood types, the blood groups of 35
Chown, B. See Lewis, M. 383
Clark, W. E. Le Gros. The antecedents of man 88
Cold Spring Harbor Symposia on Quantitative Biology, Vol. XXIV, Genetics and Twentieth Century Darwinism 409
Complete epiphyseal union of the hand 365
Correlation between external cranial volume and brain volume, the 317
Cranial volume and brain volume, the correlation between external 317
Craniometrics, a photographic method for 245

D

De George, F. V. See Osborne, R. H. 213
Demographic and methodological aspects, the reassessment of the age and sex of the Indian Knoll skeletal population: 237
Dental arches in children with good occlusion studied longitudinally from age 9 years to late adolescence, size and form of 263
Dobzhansky, Th. See Wallace, Bruce 87

E

Ellis, Richard A. See Montagna, William 1, 115
Emanuel, Irvin. See Alexander, Milton 147
England, physiques of Hawaii-born young men and women of Japanese ancestry, compared with college men and women of the United States and 173
Environment and migration: Further anthropometric findings on migrant and non-migrant Mexicans, age, 203
Epiphyseal union of the hand, complete 365
Epiphyses of the proximal phalanges, radiological studies of variation in ossification of the foot. III. Cone shaped 131
Evans, F. Gaynor. See Lasker, Gabriel Ward 203

F

Felts, William J. L. See Monson, James W. 63
Foot, radiological studies of variation in ossification of the
  III. Cone shaped epiphyses of the proximal phalanges 131
  IV. The length and growth of bones of the foot in relation to morphology 137
Fulani of Northern Nigeria and the Yoruba of Western Nigeria, the blood groups of the Pastoral 195

G

(*Galago senegalensis*), the skin of primates. IV. The skin of the lesser Bushbaby 23
Garn, Stanley M., Christabel G. Rohmann and Benjamin Apfelbaum. Complete epiphyseal union of the hand 365
Garn, Stanley M., Christabel G. Rohmann and Meinhard Robinow. Increments in hand-wrist ossification 45
Garn, Stanley M., Christabel G. Rohmann and Donald K. Wallace. Association between alternate sequences of hand-wrist ossification 361
Goajiro Indians, the blood group antigens in 255
Gordon, Eve B. See Wiener, Alexander S. 35
Gorilla Gorilla beringei, the blood vessels of the heart of 373
Gorilla (*Gorilla gorilla beringei*), the liver of the mountain 309
(*Gorilla gorilla beringei*), the liver of the mountain Gorilla 309
Growth and skeletal maturation of Chinese children in Hong Kong 289
Growth at puberty, some aspects of skeletal development through adolescence. II. The interrelationship between skeletal maturation and 333

H

Haataja, Johannes. See Koski, Kalevi 379
Hair, comparative spectrophotometric absorption of the pigments from non-red human 351
Hair from four races of men, a study of the size and shape of cross sections 345
Hall-Craggs, E. C. B. The blood vessels of the heart of Gorilla Gorilla beringei 373
Hand, complete epiphyseal union of the 365
Hand-wrist ossification, association between alternate sequences of 361
Hand and wrist in Finnish children, skeletal development of 379
Hand-wrist ossification, increments in 45
Hanna, B. L. Comparative spectrophotometric absorption of the pigments from non-red human hair 351
Hardin, Garrett. Nature and man's fate 217
Harris, H. Human biochemical genetics 220
Harrison, G. A. See Roberts, D. F. 215
Heart of Gorilla Gorilla beringei, the blood vessels of the 373
Heath, Barbara Honeyman, Carl E. Hopkins and Carey D. Miller. Physiques of Hawaii-born young men and women of Japanese ancestry, compared with college men and women of the United States and England 173
Hewitt, David, and Roy M. Acheson. Some aspects of skeletal development through adolescence.
  I. Variations in the rate and pattern of skeletal maturation at puberty 321
  II. The interrelationship between skeletal maturation and growth at puberty 333
Hildes, J. A. See Lewis, M. 383
Hopkins, Carl E. See Heath, Barbara Honeyman 173
Hsu, F. K. See Chan, S. T. 289
Human hair, comparative spectrophotometric absorption of the pigments from non-red 351
Humerus to longitudinal compressive force, transplantation studies of factors in skeletal organogenesis. II. The response of the immature mouse 63

I

Ikin, Elizabeth W. See Blumberg, B. S. 195
Increments in hand-wrist ossification 45
Infanticide on the sex ratio, the effect of polygamy and 79

J

Japanese ancestry, compared with college men and women of the United States and England, physiques of Hawaii-born young men and women of 173

JOHNSTON, FRANCIS E., AND CHARLES E. SNOW. The reassessment of the age and sex of the Indian Knoll skeletal population: demographic and methodological aspects ... 237
JØRGENSEN, JØRGEN BALSLEV, ERLING PARIDON AND FLEMMING QUAADE. The correlation between external cranial volume and brain volume ... 317

K

KAITA, H. See Lewis M. ... 383
KNOTT, VIRGINIA B. Size and form of the dental arches in children with good occlusion studied longitudinally from age 9 years to late adolescence ... 263
KOSKI, KALEVI, JOHANNES HAATAJA AND MARJA LAPPALAINEN. Skeletal development of hand and wrist in Finnish children ... 379
KRAUS, BERTRAM S. The western Apache: Some anthropometric observations ... 227

L

LAPPALAINEN, MARJA. See Koski, Kalevi ... 379
LASKER, G. W. The evolution of man ... 409
LASKER, GABRIEL WARD, AND F. GAYNOR EVANS. Age, environment and migration: Further anthropometric findings on migrant and non-migrant Mexicans ... 203
LASKER, GABRIEL WARD. The processes of ongoing human evolution ... 215
LAYRISSE, M., Z. LAYRISSE AND J. WILBERT. The blood group antigens in Goajiro Indians ... 255
LAYRISSE, Z. See Layrisse, M. ... 255
Lemur (*Lemur macaco*), the skin of primates. V. The skin of the black ... 115
(*Lemur macaco*), the skin of primates. V. The skin of the black Lemur ... 115
LEWIS, M., J. A. HILDES, H. KAITA AND B. CHOWN. The blood groups of the Kutchin Indians at Old Crow, Yukon Territory ... 383
LEWIN, T., B. TENGROTH AND B. BERGKVIST. A photographic method for craniometrics ... 245
Liver of the mountain Gorilla (*Gorilla gorilla beringei*), the ... 309
Loris (*Nyctiebus coucang*), the skin of primates. III. The skin of the slow ... 1
Lunate and triquetral centers, a note on the fusion of the ... 251

M

Mandible: an experimental and comparative study, the significance of the angle of the 55
Manned space flight vehicles and the physical anthropologist ... 185
Maturation and growth at puberty, some aspects of skeletal development through adolescence. II. The interrelationship between skeletal ... 333
Maturation at puberty, some aspects of skeletal development through adolescence. I. Variations in the rate and pattern of skeletal ... 321
Men, a study of the size and shape of cross sections of hair from four races of ... 345
Methodological aspects, the reassessment of the age and sex of the Indian Knoll skeletal population: demographic and ... 237
MILLER, CAREY D. See Heath, Barbara Honeyman ... 173
MILLER, CAREY D. Stature and build of Hawaii-born youth of Japanese ancestry 159
MONTAGNA, WILLIAM, KENJIRO YASUDA AND RICHARD A. ELLIS. The skin of primates. V. The skin of the black Lemur (*Lemur macaco*) ... 115
MONTAGNA, WILLIAM, KENJIRO YASUDA AND RICHARD A. ELLIS. The skin of primates. III. The skin of the slow Loris (*Nycticebus coucang*) ... 1
MONTAGNA, WILLIAM. See Yasuda, Kenjiro 23
MONSON, JAMES W., AND WILLIAM J. L. FELTS. Transplantation studies of factors in skeletal organogenesis. II. The response of the immature mouse humerus to longitudinal compressive force ... 63
Morphology, radiological studies of variation in ossification of the foot. IV. The length and growth of bones of the foot in relation to ... 137
MOSS, MELVIN L. Rotation of the otic capsule in bipedal rats ... 301
Mouse humerus to longitudinal compressive force, transplantation studies of factors in skeletal organogenesis. II. The response of the immature ... 63

N

(*Nycticebus coucang*), the skin of primates. III. The skin of the slow Loris ... 1

O

Occlusion studied longitudinally from age 9 years to late adolescence, size and form of dental arches in children with good ... 263
Organogenesis. II. The response of the immature mouse humerus to longitudinal compressive force, transplantation studies of factors in skeletal ... 63
OSBORNE, R. H., AND F. V. DE GEORGE. Genetic basis of morphological variation ... 213
Ossification, association between alternate sequences of hand-wrist ... 361
Ossification, increments in hand-wrist ... 45
Ossification of the foot, radiological studies of variation in
  III. Cone shaped epiphyses of the proximal phalanges ... 131
  IV. The length and growth of bones of the foot in relation to morphology ... 137
Otic capsule in bipedal rats, rotation of the 301

P

PARIDON, ERLING. See Jørgensen, Jørgen Balslev ... 317
Phalanges, radiological studies of variation in ossification of the foot. III. Cone shaped epiphyses of the proximal ... 131

Physiques of Hawaii-born young men and women of Japanese ancestry, compared with college men and women of the United States and England 173
Pigments from non-red human hair, comparative spectrophotometric absorption of the 351
Polygamy and infanticide on the sex ratio, the effect of 79
Primates, the skin of
  III. The skin of the slow Loris (*Nycticebus coucang*) 1
  IV. The skin of the lesser Bushbaby (*Galago senegalensis*) 23
  V. The skin of the black Lemur (*Lemur macaco*) 115
Proceedings of the Twenty-Ninth Annual Meeting of The American Association of Physical Anthropologists 91
Puberty, some aspects of skeletal development through adolescence. I. Variations in the rate and pattern of skeletal maturation at 321
Puberty, some aspects of skeletal development through adolescence. II. The interrelationship between skeletal maturation and growth at 333

Q

Quaade, Flemming. See Jørgensen, Jørgen Balslev 317

R

Races of men, a study of the size and shape of cross sections of hair from four 345
Radiological studies of variation in ossification of the foot.
  III. Cone shaped epiphyses of the proximal phalanges 131
  IV. The length and growth of bones of the foot in relation to morphology 137
Rats, rotation of the otic capsule in bipedal 301
Reassessment of the age and sex of the Indian Knoll skeletal population: demographic and methodological aspects, the 237
Rh-Hr (CDE/cde) blood types, the blood groups of Chimpanzees: the 35
Roberts, D. F., and G. A. Harrison. Natural selection in human populations . . 215
Robinow, Meinhard. See Garn, Stanley M. 45
Robinson, John T. The dentition of the australopithecinae 219
Rohmann, Crhistabel G. See Garn, Stanley M. 45, 361, 365
Roe, Anne, and Simpson, George G. Behavior and evolution 218
Rotation of the otic capsule in bipedal rats 301

S

Sainis of Punjab, the study of ABO blood groups of 223
Salzano, Francisco. Studies on the Caingang Indians. III. Blood groups 391
Sassouni, Viken. The face: In five dimensions 85
Selmer-Olsen, Reider. An odontometrial study on the Norwegian Lapps 8
Setty, Laurel Raymond. Distribution of chest hair in caucasoid males 28
Sex of the Indian Knoll skeletal population: demographic and methodological aspects 23
Shaw, Richard F. The effect of polygamy and infanticide on the sex ratio 7
Significance of the angle of the mandible: an experimental and comparative sutdy, the 5
Simpson, George G. See Roe, Anne 21
Singh, Darshan. See Singh, Indera P. 22
Singh, Indera P., and Darshan Singh. The study of ABO blood groups of Sainis of Punjab 22
Size and form of the dental arches in children with good occlusion studied longitudinally from age 9 years to late adolescence 26
Skeletal development through adolescence, some aspects of
  I. Variations in the rate and pattern of skeletal maturation at puberty 32
  II. The interrelationship between skeletal maturation and growth at puberty . . . 333
Skeletal development of hand and wrist in Finnish children 379
Skeletal maturation and growth at puberty, some aspects of skeletal development through adolescence. II. The interrelationship between 333
Skeletal maturation at puberty, some aspects of skeletal development through adolescence. I. Variations in the rate and pattern of 32
Skeletal maturation of Chinese children in Hong Kong, growth and 289
Skeletal organogenesis. II. The response of the immature mouse humerus to longitudinal compressive force, transplantation studies of factors in 63
Skeletal population: demographic and methodological aspects, the reassessment of the age and sex of Indian Knoll 237
Skin of primates, the
  III. The skin of the slow Loris (*Nycticebus coucang*) . . . .
  IV. The skin of the lesser Bushbaby (*Galago senegalensis*) 23
  V. The skin of the black Lemur (*Lemur macaco*) 115
Skin of the black Lemur (*Lemur macaco*), The skin of primates. V. the 115
Skin of the lesser Bushbaby (*Galago senegalensis*), the skin of primates. IV. The 23
Skin of the slow Loris (*Nycticebus coucang*), the skin of primates. III. The 1
Snow, Charles E. See Johnston, Francis E. 237
Snyder, Richard G. Manned space flight vehicles and the physical anthropologist 185
Spectrophotometric absorption of the pigpigments from non-red human hair, comparative 351
Stature and build of Hawaii-born youth of Japanese ancestry 159
Studies on the Caingang Indians. III. Blood groups 391

Study of ABO blood groups of Sainis of Punjab, the 223
Study of the size and shape of cross sections of hair from four races of men, a 345

T

Tengroth, B. See Lewin, T. 245
Transplantation studies of factors in skeletal organogenesis. II. The response of the immature mouse humerus to longitudinal compressive force 63
Triquetral centers, a note on the fusion of the lunate and 251

U

United States and England, physiques of Hawaii-born young men and women of Japanese ancestry, compared with college men and women of the 173

V

Venning, P. Radiological studies of variation in ossification of the foot.
  III. Cone shaped epiphyses of the proximal phalanges 131
  IV. The length and growth of bones of the foot in relation to morphology 137
Vernall, Donald G. A study of the size and shape of cross sections of hair from four races of men 345
Viking Fund Medalist for 1960 (Sherwood L. Washburn) 405

W

Wallace, Bruce, and Th. Dobzhansky. Radiation, genes, and man 87
Wallace, Donald K. See Garn, Stanley M. 361
Western Apache: some anthropometric observations, the 227
Wetherington, Ronald K. A note on the fusion of the lunate and triquetral centers 251
Wiener, Alexander S., and Eve B. Gordon. The blood groups of Chimpanzees: The Rh-Hr (CDE/cde) blood types 35
Wilbert, J. See Layrisse, M. 255
Wrist in Finnish children, skeletal development in hand and 379

Y

Yasuda, Kenjiro. See Montagna, William 1, 115
Yasuda, Kenjiro, Tsuyoshi Aoki and William Montagna. The skin of primates. IV. The skin of the lesser Bushbaby (*Galago senegalensis*) 23
Yoruba of Western Nigeria, the blood groups of the pastoral Fulani of Northern Nigeria and the 195
Youth of Japanese ancestry, stature and build of Hawaii-born 159

Z

Zeigen, Robert S. See Alexander, Milton 147

BIOLOGICAL ABSTRACTS

is growing with the literature

Because of the phenomenal growth in the biological research literature, published originally in thousands of journals throughout the world, an adequate abstracting and indexing service has become indispensable. Perhaps some relatively obscure journal has published a revealing paper on the very subject in which you are most interested. If it is a significant contribution, an informative abstract of it will be found in *Biological Abstracts*.

Now publishing at the rate of at least 100,000 abstracts per annum in 24 semi-monthly issues, *Biological Abstracts* is published in a complete edition covering all areas of biology, and in five comparatively low-priced sectional editions that are designed specially to meet the needs of individual biologists. So that this cooperative service may be available to all biologists, individual subscribers are allowed a special discount of 50% off the list prices of these sectional editions. Write for complete information and a sample copy.

BIOLOGICAL ABSTRACTS
UNIVERSITY OF PENNSYLVANIA
PHILADELPHIA 4, PA.

THE AMERICAN JOURNAL OF

HUMAN GENETICS

A quarterly record of research, review and bibliographic material relating to heredity in man

Official Journal of THE AMERICAN SOCIETY OF HUMAN GENETICS

Editor: C. NASH HERNDON, M. D.

Bowman Gray School of Medicine, Winston-Salem, North Carolina

The editor and his staff of associates will be glad to consider manuscripts pertaining to human genetics.

Subscription to THE AMERICAN JOURNAL OF HUMAN GENETICS or information pertaining to subscription should be addressed to Grune & Stratton, Inc., 381 Park Avenue South, New York 16, N. Y. The subscription price per volume is $10.00. A volume consists of 4 numbers. Single numbers cost $3.00. The first volume was published in 1949. One volume has been published each year since then.

Correspondence pertaining to membership in THE AMERICAN SOCIETY OF HUMAN GENETICS or to general society affairs should be addressed to the Secretary of the Society, Dr. S. H. Boyer, Department of Medicine, Johns Hopkins Hospital, Baltimore 5, Maryland.